The dental and orthodontic features, baseline anxiety and quality of life of children referred to a specialist centre for management of first permanent molars with Molar Incisor Hypomineralisation (MIH) or Caries

By

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Abstract

Introduction: Children may present with first permanent molars (FPM) affected by Molar Incisor Hypomineralisation (MIH), Caries, or other dental defects.

Aims: To describe the dental and orthodontic features, dental anxiety and oral-health-related quality-of-life (OHR-QoL) of children requiring management of FPM. To identify the factors clinicians consider when deciding on management of poor-quality FPM.

Methods: A descriptive observational study, prospectively recruited 105 children aged 6-12 referred for management of FPM affected by MIH(n=82), Caries(n=20), and Amelogenesis Imperfecta(n=3). Demographics, baseline dental anxiety and OHR-QoL using self-reported questionnaires (MCDASf, COHIP-SF19), clinical records (photographs, OPT radiographs, study models), and clinicians' clinical assessment and treatment-planning were explored. Through a web-based survey, factors influencing clinicians' planning of children with compromised FPM were investigated.

Results: There was no difference in anxiety scores between MIH-group and Caries-group children; although MIH children were more anxious of 'having a filling'. Caries children had poorer OHR-QoL. There were no differences in orthodontic treatment need between Caries and MIH children, although Caries children had significantly more dental crowding.

Each category of FPM management plan was significantly associated with:

- *Extraction:* Caries-group children; lower second permanent molar (SPM) bifurcation (stage E); Frankl behaviour (-); poor oral-hygiene rating; class I skeletal pattern; deviant trait crowding.
- *Restoration:* skeletal Class II.
- *Temporisation/review:* younger chronological age (7.8); younger dental age (7.7); earlier developmental stage of lower SPM (stage D).
- 15.0% of children had elective FPM extractions, and Caries-group children had significantly increased proportions.

Mode of treatment was significantly associated with:

- *GA:* Caries-group children; poor oral-hygiene rating; Frankl behaviour (+) or (-); elective FPM extractions.
- *LA:* Frankl behaviour (++).

The reasons most commonly considered by paediatric dental clinicians when treatment planning for children with poor-quality FPM were: patient behaviour/cooperation(75.6%), FPM restorability(70.7%), and presence/absence of developing teeth(68.8%).

Conclusion: Many variables were associated with the planning of children with poor-quality FPM.

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1 Literature Review

1.1 Introduction

The quality of first permanent molars (FPM) can be affected by several conditions, which may compromise their prognosis. The FPM erupts early in the oral environment, which renders it vulnerable to dental caries (Pitts et al., 2006). Dental caries has been reported as the commonest reason for FPM extraction (Albadri et al., 2007). The timing of FPM development can contribute to its vulnerability, where it begins to calcify at birth, and is therefore more susceptible to chronological defects such as enamel hypomineralisation and enamel hypoplasia (Leppaniemi et al., 2001). Another common reason for the prognosis of FPM to be compromised is the increasingly recognised incidence of Molar Incisor Hypomineralisation (MIH), which causes demarcated enamel defects with or without symptoms (Koch et al., 1987).

1.2 MIH

MIH is a condition in which the enamel of at least one FPM is affected with a qualitative defect causing abnormal translucency appearing as demarcated opacities; and is frequently associated with affected incisors (Weerheijm et al., 2015, 2003). In some instances, second primary molars, second permanent molars, and tips of the permanent canines could also be affected (Jälevik, 2010; Elfrink et al., 2008).

MIH should be distinguished from other differential diagnoses including Amelogenesis Imperfecta (AI), chronological hypoplasia, and dental fluorosis. Enamel defects seen in MIH can be clinically distinguished by the characteristic of the opacity appearing demarcated, commonly involving the occlusal and/or incisal third of one or more permanent molars and/or incisors, as opposed to the more diffuse appearance in dental fluorosis, and the generalised distribution in AI (Weerheijm, 2004; Weerheijm et al., 2001).

1.2.1 MIH aetiology

Many studies have investigated aetiology of MIH, which remains uncertain, but appears to be multifactorial, as demonstrated in Figure 1-1 (dos Santos & Maia, 2012; Whatling & Fearne, 2008). The formation of dental tissues including enamel, dentine, and cementum are controlled by genes and influenced by epigenetic and environmental factors (Seow, 2014; Brook, 2009).

The asymmetrical presentation of enamel defects in MIH, as opposed to the symmetrical presentation of chronological hypoplasia may point to a genetic factor rather than an environmental cause; although the body is known to develop asymmetrically and different groups of ameloblasts could be active at the time of the environmental insult (Whatling & Fearne, 2008). A number of systemic factors affecting the supply of oxygen to the ameloblast is thought to affect the maturation of the enamel and cause hypomineralisation (Whatling & Fearne, 2008).

The development of MIH has been associated with perinatal factors such as premature birth (Brogardh-Roth et al., 2011) caesarean delivery (Pitiphat et al., 2014) and low birth weight (Ghanim et al., 2013a); although other studies did not find such findings (Jälevik et al., 2001b). MIH has also been associated with childhood illness in the first few years of life including fever (Sönmez et al., 2013; Ghanim et al., 2013a), asthma (Pitiphat et al., 2014; Jälevik et al., 2001b), upper respiratory tract infections including otitis media (Jälevik et al., 2001b), and antibiotic use (Ghanim et al., 2013a). Furthermore, respiratory conditions were found to be associated with a severe form of MIH involving the incisors (Kuhnisch et al., 2014). Although aerosol therapy for treatment of respiratory diseases was reported as a risk factor for the development of MIH, interestingly, its use with a spacer and rinsing with water afterwards was found to be a protective factor (Loli et al., 2015).

Pollutants in the environment known as Dioxins (polychlorinated dibenzo-p-dioxins) and PCB (polychlorinated byphenyls) enter mother's breast milk via the food chain and were thought to disturb dental development in the form of hypomineralised enamel defects (Alaluusua et al., 1996). The authors of this study revisited this 12 years later in a prospective study, and concluded that exposure of Dioxins and PCB in mother's milk was not associated with MIH after all (Laisi et al., 2008). Nevertheless, other studies found that breastfeeding more than 6 months was significantly associated with MIH (Fagrell et al., 2011). Furthermore, Balmer (2013) found that breastfeeding on discharge was significantly associated with the occurrence of MIH with a 2.8 odds ratio compared to controls; although there was no relationship with labour onset, labour duration, nor mode of delivery.

Medical problems during pregnancy, and children's systemic conditions are thought to have a synergistic affect for the occurrence of enamel defects, rather than a specific condition being a single causative factor (Fagrell et al., 2011; Lygidakis et al., 2010; Crombie et al., 2009; Whatling & Fearne, 2008; Seow, 1991). Overall, there is insufficient strong evidence in the literature related to aetiological factors that contribute to the development of MIH (Crombie et al., 2009).

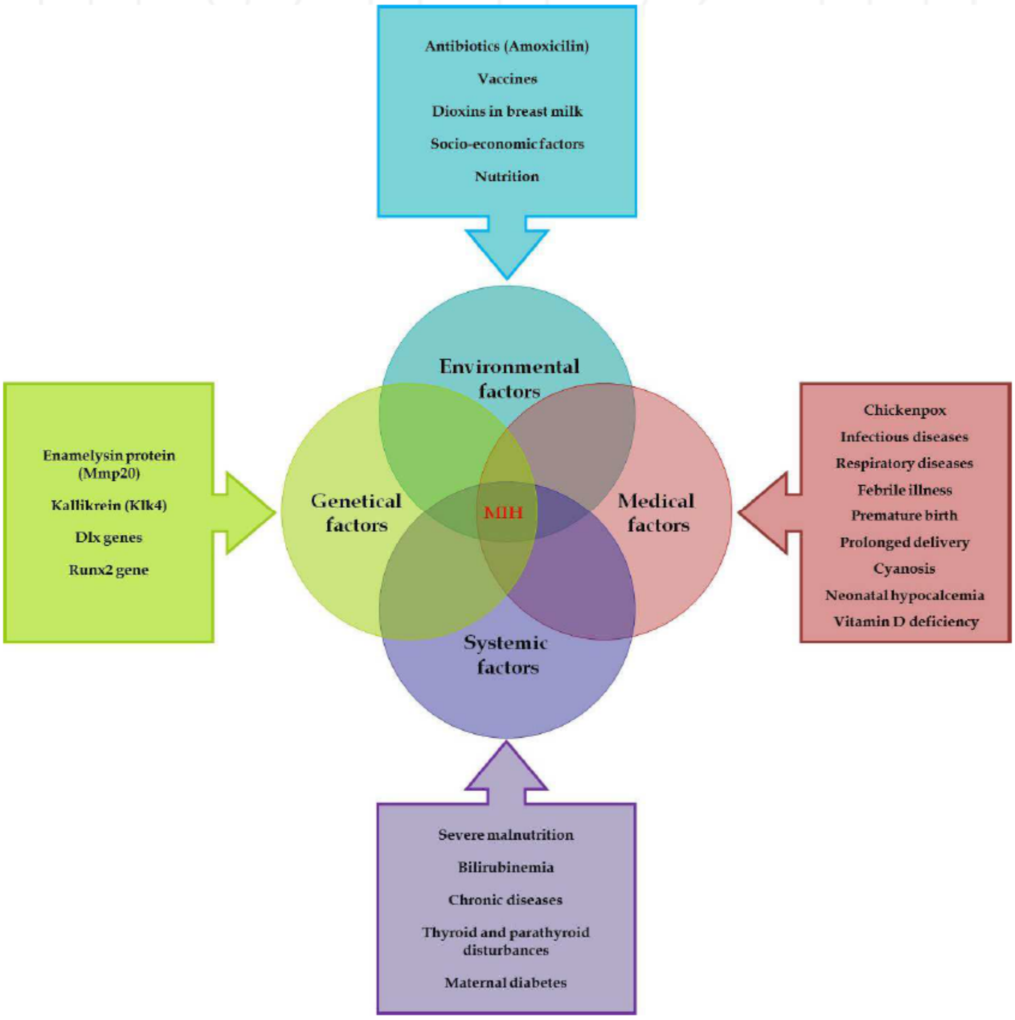


Figure 1-1: The multifactorial aetiology of MIH (dos Santos & Maia, 2012)

1.2.2 MIH prevalence

Studies around the world had investigated prevalence of MIH, which ranged from 2.8% in Hong Kong (Cho et al., 2008) to 5.6% in Germany (Dietrich et al., 2003), 15.9% in Northern England (Balmer et al., 2012), 18.4% in Sweden (Jälevik et al., 2001a), 22% in Australia (Arrow, 2008), 27.7% in Thailand (Pitiphat et al., 2014), and up to 40% in Brazil (Soviero et al., 2009). The overall average MIH prevalence from 59 studies has been reported as 16% by The D3 group (2016), as presented in Figure 1-2.

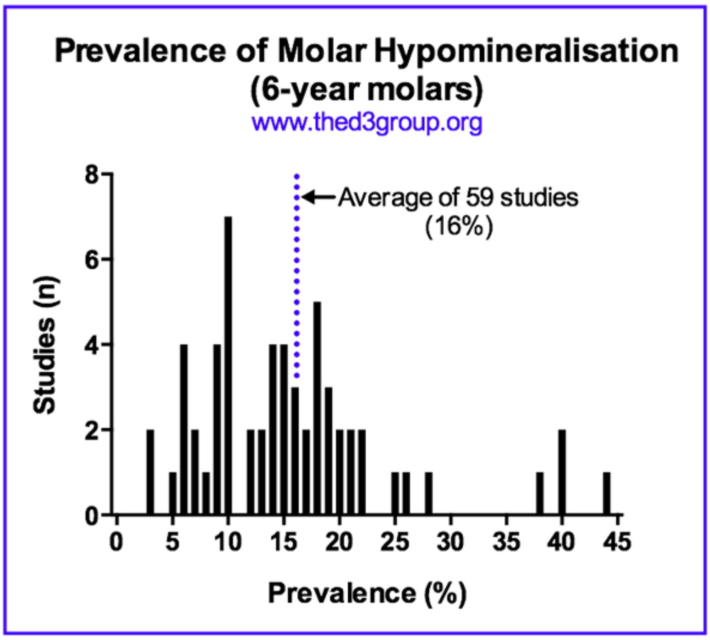


Figure 1-2: Average prevalence of MIH (The D3 Group, 2016)

1.2.3 MIH and the FPM

FPM affected by MIH clinically present with demarcated opacities that vary in colour from white, cream, yellow to brown and present as a clear demarcation between the affected and sound enamel. The severity of MIH can also vary from mild defects with demarcated opacities, to moderate/severe defects with enamel breakdown and atypical restorations (Lygidakis et al., 2008).

MIH-affected FPM have hypomineralised enamel, which is weaker and therefore, easily lost under normal masticatory function causing post eruptive enamel breakdown (PEB). This would expose the underlying dentine, and render the tooth at risk of developing rapid decay (Weerheijm et al., 2001); leading to sensitivity ranging from mild to spontaneous hypersensitivity, where successful anaesthesia may be difficult to achieve (Lygidakis et al., 2010). Dentine hypersensitivity has also been attributed to the presence of pulpal inflammation in hypomineralised molars, regardless of whether PEB or caries are present or not (Rodd et al., 2007).

1.2.4 MIH management

Management of FPM affected by MIH can be challenging and there are several factors which contribute to this. Due to the poor quality enamel on affected FPM, dental caries can develop rapidly and sensitivity may occur, which also would contribute to causing limited cooperation of the child to dental treatment (William et al., 2006). A Swedish study by Jälevik & Klingberg (2002) has shown that at 9 years old, children with MIH displayed dental anxiety and were more likely to have behaviour management problems compared to controls. Furthermore, it was found that they had up to 10 times more frequent treatment on FPM than controls; although many were performed without local anaesthesia (LA). Similarly, a Greek study found that MIH children had 11 times the probability of undergoing restorative treatment on FPM, compared to controls (Kotsanos et al., 2005). Not only is pulpal anaesthesia in hypomineralised FPM sometimes difficult to achieve, but restorations would commonly undergo repeated marginal breakdown, requiring repeated replacement (William et al., 2006).

Management of FPM affected by MIH often requires a multidisciplinary approach. Treatment options may include maintaining the affected FPM with suitable restoration methods such as desensitising agents, fissure sealants, intra-coronal restorations using composites or resin-modified glass ionomers, and extra-coronal restorations including adhesively-retained onlays or cuspal overlays (Fayle, 2003). A prospective study had found that preformed metal crowns (PMC) and cast metal restorations were equally successful on posterior teeth in children with enamel defects (Zagdwon et al., 2002).

The mineral content of hypomineralised teeth could be improved after its eruption with the use of the milk-based protein CPP-ACP (Casein Phosphopeptide-Amorphous Calcium Phosphate) with or without fluoride; which encourages mineralisation on the surface, as well as deeper within enamel (Baroni & Marchionni, 2011). The use of caries infiltrate resin has been shown penetrate MIH- affected enamel, although its efficacy in vitro was variable and erratic (Crombie et al., 2014).

MIH-affected FPM have lifelong costs and maintenance implications, as 50% of 18 year-olds with MIH were found to have additional treatment needs (Mejàre et al., 2005). Dentists may therefore encounter patients in the mixed dentition phase with FPM of questionable prognosis and will need to face the decision of whether to restore or extract affected FPM.

1.3 Extraction of the FPM

Evaluating whether to restore or extract an affected FPM relies on many factors including dental age, orthodontic considerations such as crowding and skeletal base relationship, existing developmental anomalies such as hypodontia, and tooth factors related to the condition and prognosis of the affected teeth (Fayle, 2003; Gill et al., 2001).

An EAPD policy document on MIH management discussed many treatment approaches for affected FPM, one of which includes extraction and orthodontic management (Lygidakis et al., 2010). FPM extraction was recommended at a dental age of 8.5-9 years. This is in agreement with Williams and Gowans (2003), who based the ‘ideal age’ recommendation of 8-9 years on Thunold’s (1970) 25-year follow-up study of early loss of FPM; as well as the UK guidance on FPM extractions in children (Cobourne et al., 2014, 2009).

1.3.1 Orthodontic considerations of FPM extraction

Extracting an FPM would not be an orthodontist’s first choice, as it may further complicate or increase the duration of orthodontic treatment; however, in cases where FPM prognosis is compromised due to hypomineralisation or caries, their extraction could be more beneficial in the long term (Williams & Gowans, 2003). In such cases, elective extraction of a healthy premolar for orthodontic reasons may not be justifiable (Ong & Bleakley, 2010).

A thorough clinical evaluation, radiographic examination using an OPT radiograph, as well as having a close relationship between the Paediatric dentist and the Orthodontist are often essential for obtaining a favourable outcome in the child patient (Williams & Gowans, 2003).

1.3.2 Early and late FPM extraction

Extraction of the lower FPM earlier than 8-9 years, may pose a risk of the developing lower second premolars tilting distally, as they escape the bifurcation of the primary predecessor and erupt distally into the less-resistant path through the FPM extraction socket (Ong & Bleakley, 2010; Williams & Gowans, 2003; Gill et al., 2001). To prevent this from occurring, Williams and Gowans (2003) advised the lower second primary molars to be extracted at the same time as the FPM, to allow free eruption of the lower second premolar. There were no such results found in any of the subjects of Jälevik and Möller’s (2007) study; where early-age FPM extractions had a good spontaneous space closure and a favourable development of occlusion. Early extraction of FPM in the lower arch may also cause the labial segment to retrocline, resulting in an increased overbite (Cobourne et al., 2014; Richardson, 1979; Thunold, 1970).

Extraction of a lower FPM may allow the upper FPM to be unopposed for a prolonged period of time with a risk of over-erupting. In severe cases, upper FPM over-eruption may impede the spontaneous mesial movement of the lower SPM (Ong & Bleakley, 2010). This has been the reasoning behind considering elective compensating extractions of upper FPM in mixed dentition cases; although there is a lack of strong evidence to support this (Cobourne et al., 2014).

A common rationale for FPM to be extracted at the 'ideal' time is that extraction at a later time outside of that window may result in unfavourable effects such as tipping of adjacent teeth and minimal space closure (Cobourne et al., 2014, 2009).

1.3.3 FPM extraction and space closure

Guidance has been developed by the Royal College of Surgeons (RCS) (Cobourne et al., 2014, 2009) and generally recommends FPM extractions to be timed at age of around 8-10 years. Although former RCS guidance have recommended that the ideal time for FPM extraction is when the root bifurcation of the SPM start to form (Demirjian stage E, Appendix 14), the updated guidance acknowledges that this may not be a precise predictor, as SPM positioning can be acceptable regardless of its developing stage during FPM extraction (Cobourne et al., 2014; Teo et al., 2013). With regard to timing and dental development, the RCS guidance recommends FPM extraction after eruption of the lateral incisors, but before eruption of the SPM and/or second premolars (Cobourne et al., 2014).

A retrospective study assessing spontaneous space closure following 236 FPM extractions from 63 patients found that only 66% of lower FPM extracted at the recommended dental age resulted in favourable space closure. In the upper arch however, most (92%) FPM extractions resulted in complete space closure, regardless of the SPM developmental stage (Teo et al., 2013). This study found no significant relationship between SPM development stage and favourable development with space closure of either arch. Although over half of the patients had FPMs extracted at the 'ideal time' window, this did not appear to influence successful positioning of the upper nor lower SPM. Therefore, timing alone is not enough to predict space closure, and other parameters may have a significant effect on post-extraction orthodontic development; particularly in the lower arch (Teo et al., 2013).

More recently, Teo et al. (2016) investigated radiographic factors to help predict the degree of spontaneous space closure of lower SPM following FPM extraction. It was found that mesial angulation of the lower SPM combined with the presence of the third permanent molars were strong predictors of spontaneous space closure; and 85% with those features had complete space closure (Teo et al., 2016).

1.3.4 FPM extraction in the long term

There is a shortage of studies which help conclude the long-term prognosis and treatment outcomes for the loss of FPM. Children presenting with compromised FPM, are therefore difficult to address and manage. Mejare et al. (2005) and Jälevik and Möller (2007) had investigated this using retrospective study designs.

Mejäre et al. (2005) conducted a retrospective study with an average of 10 years follow-up of 76 MIH patients, treated in a dental institute in Sweden from 1978-2001, with a mean follow-up age of 18 years. They aimed to retrospectively evaluate the treatment outcome of patients with MIH, and found that for those treated with extraction of one or more FPM, 87% had satisfactory dental occlusion and space closure. The study found that unacceptable space closure was twice as common in the lower arch compared to the upper arch. This was also in agreement to Teo et al.'s (2013) findings.

Jälevik and Möller (2007) conducted a retrospective study in Sweden with a cohort of 27 patients followed-up 3 to 8 years after FPM extractions. Results of this study showed that 15 out of the 27 cases had good occlusal development with SPM drifting into FPM extraction space; of which extractions took place between the ages of 6.2-12.3.

1.3.5 Current controversy surrounding FPM extraction

FPM extraction can be a controversial subject with differing opinions regarding the most appropriate clinical management. Traditionally, the attempt was made to restore FPM where possible due risk of unfavourable outcomes such as over-eruption of opposing teeth or tipping of adjacent teeth. The RCS guideline, however, described that FPM extractions can be planned at a certain timing to allow the SPM to erupt in the position of the lost FPM (Cobourne et al., 2014, 2009). The recommendation of optimum FPM extraction timing between the ages of 8 to 10 years is largely based on data published in the 1970's (Richardson, 1979; Williams & Hosila, 1976; Thunold, 1970; Plint, 1970). Studies linking timing of extraction with favourable occlusal development are not very robust.

There is a lack of conclusive long-term data associating FPM extractions with certain orthodontic outcomes (Teo et al., 2013; Williams & Gowans, 2003). Furthermore, there is a deficiency of robust evidence underlying the critical recommendation of optimum timing and patterns of FPM extraction (Williams & Gowans, 2003). Therefore, the fact that spontaneous space closure would be assumed to take place if FPM are extracted at an 'ideal' age seems open to question; and further studies to explore this would be of benefit.

1.4 Dental anxiety and oral-health-related QoL

Poor quality FPM affected by MIH can be very sensitive and those affected by dental caries can be painful. If left untreated, such teeth can be a risk of infection. Compromised FPM can therefore have an impact on the patient's daily life such as interfering with nutrition and oral hygiene difficulties further complicating the condition (Fayle, 2003). It would be beneficial to measure how much of an impact these conditions have prior to definitive treatment by assessing levels of dental anxiety and impact on quality of life (QoL) by means of simple questionnaires at the initial specialist consultation assessment.

1.4.1 Dental anxiety

Dental anxiety is not uncommon, and is generally higher in children with dental pathology or whom had traumatic dental visits (Townend et al., 2000). There are many scales in the literature that quantify dental anxiety. Difficulties in measuring dental anxiety may arise from failure to address the many factors that may result in the fear and anxiety response (Armfield, 2010). Anxiety levels are commonly measured using questionnaires. When assessing the level of dental anxiety in children, one must use questions worded to the level of the child's understanding; otherwise, inconsistencies or inaccuracies in anxiety scores may occur. Questionnaires could be used on older children with a larger vocabulary and emotional capacity, whereas younger children have varying levels of limited vocabulary, understanding, and emotional development (Cuthbert & Melamed, 1982).

The Five Areas Model of anxiety was explained by Williams and Garland (2002). Thoughts, feelings, behaviours, physical symptoms, and situation all can play a role in setting a child's anxiety levels. It benefits practitioners in that it allows them to identify certain areas that impact their anxiety; hence relevant psychological treatment can be targeted and planned. Changes to any of the five areas, would result in changes in the other areas (Williams & Garland, 2002); as adapted in cognitive behavioural therapy (CBT) for the management of dental anxiety in children (Marshman et al., 2016).

1.4.1.1 Dental anxiety – self-reported methods

Self-reported methods of measuring dental anxiety has been systematically reviewed by Porrit et al. (2013). These methods, which involves the child assessing themselves, are a reliable way to quantify anxiety; as opposed to proxy parent-reported methods, which may not be as reliable (Porritt et al., 2013). A review by Aartman et al. (1998) reported only three self-report measures of dental anxiety available at the time of publishing. In a more recent review however, nine different self-report methods of assessing children's anxiety were reported (Porritt et al., 2013). This shows the increasing availability of the many anxiety assessment methods available for clinicians and researchers to select from. Self-reported methods of dental anxiety include: children's fear survey schedule dental subscale (CFSS-DS), Dental Anxiety scale and its modified version (DAS, MDAS), Modified Child Dental Anxiety scale and its faces version (MCDAS, MCDASf), Dental Fear Schedule Subscale short form (DFSS-SF), Facial Image Scale (FIS), Venham Picture Scale (VPS), Dental Fear Survey and its modified version (DFS), Smiley Faces Programmes and its revised version (SFP), and Dental Anxiety Inventory short version (S-DAI).

It was emphasised that there is no one best method of measuring children's dental anxiety and that selecting an assessment method depends on what type of information is meant to be collected. Different anxiety tools are suitable for different situations such as: clinical, service organization, surveys and research purposes (Porritt et al., 2013). For the clinical and treatment planning setting, MCDAS/MCDASf, SFP, and the DFS are useful tools to quantify dental anxiety. Their useful properties include: suitability for a wide age range, short and not time-consuming, related to specific dental procedures, and developed with children in mind. FIS is suitable for when a clinician needs a prompt measure of what the child patient is feeling at a certain point in time. For survey and research purposes, scales such as the MCDAS/MCDASf, CFSS-DS, and DAS/MDAS are suitable. Clear cut-off points are an important property to have in an assessment method suitable at a service-organization level: MCDAS/MCDASf and CFSS-DS (Porritt et al., 2013).

The CFSS-DS is the most widely used scale in measuring dental anxiety in children (Porritt et al., 2013; Armfield, 2010). Many studies claim that the CFSS-DS is a reliable and valid way of measuring children's dental fear; however, this scale includes specific parts of dental treatment stimulating fear, but does not give a holistic measure (Armfield, 2010). The theory behind this scale was never explained, hence making the CFSS-DS, according to Armfield (2010), the most questionable of the scales he had discussed in his report.

Most of the self-report assessment methods in assessing dental anxiety have a clear lack of underlining sciences behind dental anxiety. Porritt et al. (2013) suggested that further development of existing measures with application of theoretical science would be of benefit.

1.4.1.2 Dental anxiety in this study – MCDASf

It is useful to think about what type of information is required to be collected when deciding on a dental anxiety assessment method. For survey and research purposes, features such as reproducibility, acceptable psychometric properties, and clear cut-off points at a service organization level are beneficial and advantageous to have (Porritt et al., 2013).

After careful review of these scales, the MCDAS (Wong et al., 1998) seemed suitable to measure dental anxiety in the cohort of patients in this study, as it has the above mentioned properties (Porritt et al., 2013). This scale has eight items, which are scored from 1 (relaxed) to 5 (very worried) and ranges from 8 to 40, where the cut-off for 'anxious' is more than 26. The faces version of this scale MCDASf (Howard & Freeman, 2007) has been chosen to be employed, as it is suitable for children in the age range of the study group, 6-12 years (Appendix 11). Advantages of this scale include high internal reliability and the ability to distinguish between children with and without dental anxiety (Porritt et al., 2013).

1.4.1.3 Dental anxiety and MIH

Swedish studies by Jälevik and Klingberg (2002) investigated a group of 9-year-old patients with MIH affecting FPM and found that parents of these children reported more dental fear and anxiety compared a control group of the same age. A CFSS-DS questionnaire answered by the parents was used to measure dental fear and anxiety. A further study by the same authors followed-up these severe MIH patients at an adolescent age of 18 years, and reported no difference in self-reported dental fear and anxiety compared to controls (Jälevik & Klingberg, 2012). The anxiety scale in Jälevik and Klingberg's first study (2002) was parent-reported; whereas their follow-up study (2012) was patient-reported by a CFSS-DS questionnaire sent through the post. However, in this present study, a self-reported tool to measure dental anxiety has been used.

1.4.2 Oral-health-related QoL

QoL is a valuable health outcome measure, which is multidimensional and plays an important part of general health. Incorporating oral-health-related QoL in research and clinical practice can therefore benefit patients, dental practices, clinical research, and may have an influence on public health policy (Sischo & Broder, 2011; Inglehart & Bagramian, 2002).

There are different measures of QoL, and their use depends on the purpose of the study. Dunlow et al. (2007) divided the QoL measures into three categories: condition-specific, dimension-specific, and general. In this current study a QoL tool from the condition-specific category was suitable; as the study looks into patients with a condition affecting their FPM. An example of a condition-specific QoL measure is Child Oral Health Impact Profile (COHIP). It is useful when investigating the effect of dental treatment on oral health outcome in children or for epidemiologic studies of oral health impact. The reason why this measure is useful in these studies is because the assessment is focused on a specific condition on oral health, and therefore has increased sensitivity to treatment effects and is relevant to the participants, enabling increased patient responsiveness to the COHIP tool (Dunlow et al., 2007).

1.4.2.1 COHIP

The COHIP is the first child self-reported oral-health-related QoL questionnaire, which incorporates a mixture of positive and negative wording to help evaluate both positive and negative health impacts (Sischo & Broder, 2011; Broder & Wilson-Genderson, 2007). It has 34 items and 6 distinct subscales: oral health wellbeing, functional wellbeing, social-emotional wellbeing, school-environment, and self-image, and treatment expectations (Broder & Wilson-Genderson, 2007).

The COHIP has been shown to be reliable in measuring oral-health-related QoL for use in epidemiological studies, and showed excellent reliability in school children (Broder & Wilson-Genderson, 2007; Dunlow et al., 2007). One of the major disadvantages of the COHIP is the length of the questionnaire consisting of 34 items (Slade & Reisine, 2007). A lengthy questionnaire can be an inconvenience to participants and requires excessive personnel time.

Children in this present study completed a questionnaire related to dental anxiety (MCDASf). Thereofere, the tool used to measure QoL should be short and simple to complete. This is to avoid participant fatigue bias, as well as minimise disruption during initial consultation appointment and recruitment; although appropriate psychometric properties should still be maintained.

1.4.2.2 QoL in this study – COHIP-SF19

For this present study, the Child Oral Health Impact Profile-short Form (COHIP-SF19) was used, as reliability and validity in measuring oral-health-related QoL in school aged paediatric children was demonstrated (Broder et al., 2012). This was done using 1175 children aged 7 to 17, including paediatric, orthodontic, and craniofacial anomalies patients. The COHIP-SF19 is shorter and more efficient with a reduced number of 19 questions and 3 subscales (oral health wellbeing, functional wellbeing, social-emotional wellbeing); as opposed to the original COHIP with 34 questions and 6 subscales.

The COHIP-SF19 is an efficient QoL assessment tool, which is appropriate for clinical research and epidemiological studies due to its ability to measure across different clinical groups, as well as within groups by extent of disease/defect (Broder et al., 2012).

1.4.2.3 Oral-health-realted QoL and FPM defects

A study done in Western Australia by Arrow (2013) aimed to investigate whether there is a connection between the oral-health-related QoL of children with FPM enamel defects and caries in the primary dentition. According to the author, previous reports imply that children with enamel defects have more fear towards dental treatment and experience significant discomfort, especially those with defects where enamel is broken-down or missing. Enamel defects and extent of caries in the primary dentition were assessed in 522 children of mean age 7.2 in pre-primary schools in Perth, Australia with the use of the mDDE index; and QoL was parent-reported. Arrow (2013) concluded that children presenting with enamel defects in their FPM did not have an impact on their oral-health-related QoL, whereas those children presenting with dental decay (higher dmft) presented with poorer oral health related QoL, suggesting its significant impact.

In this present prospective study, however, the COHIP-SF19 was used because it is self-reported and has high validity and reproducibility.

1.5 Rationale for conducting this study

Longitudinal outcome data of anxiety, QoL, dental and orthodontic features of children with poor quality FPM affected with MIH or caries is currently lacking. It therefore seemed appropriate to conduct a study, which investigated children referred to a specialist centre for management of FPM with MIH or other conditions where FPM are compromised; and to describe their presenting dental and orthodontic features, as well as associated factors that might affect their management and treatment planning by the clinician.

When considering extraction of MIH-affected FPM, the UK guidelines may play a role in this decision process; however, it is not clear whether clinicians are following this guidance or whether other variables are being used to make these decisions.

The results of this study will be used as a basis for a future subsequent study, where reassessment of these variables would help evaluate the outcomes of various treatment interventions in the cohort when they are fully established in the permanent dentition. The results gained from this study adds knowledge to help improve management and future care of children with poor quality FPM.

2 Study Summary

2.1 Title

The dental and orthodontic features, baseline anxiety and quality of life of children referred to a specialist centre for management of first permanent molars with Molar Incisor Hypomineralisation (MIH) or Caries

2.2 Aims & Objectives

- To describe the presenting clinical dental and orthodontic features of children referred to a specialist centre for management of FPM affected by MIH and/or dental caries.
- To investigate baseline levels of dental related anxiety and oral health related QoL at initial specialist consultation.
- To investigate which variables clinicians consider most important when deciding upon extraction vs retention of FPM.
- To facilitate future research to subsequently assess the outcome of the interventions provided for the management of FPM in these patients.

2.3 Primary outcome measure

Dental and orthodontic features, the baseline anxiety level, and oral health related QoL of 100 children referred to the Leeds Dental Institute (LDI) for management of FPM either affected with hypomineralisation (MIH) or caries.

2.4 Secondary outcome measures

- Identification of the factors clinicians find most important when making decisions about management of defective FPM.
- The prevalence and distribution of enamel defects of FPM, permanent incisors, and primary molars in MIH children.
- Establishing a cohort of patients to enable future research to subsequently analyse treatment outcome for the cohort.

2.5 Study endpoint

Recruitment of 100 patients who fulfilled the inclusion criteria, consented, and had their dental and orthodontic status captured, as well as their dental anxiety and QoL at initial presentation, including factors affecting clinicians' decision-making for these patients.

2.6 Treatment schedule

Patients recruited over a period of 13 months (April 2015 – May 2016)

2.7 Study process

Stage 1. **Prioritisation stage**

The primary investigator [HB] with the help of the triage team identified potential participants at receipt of original referral letters and marked them with a red stamp labelled 'FPM Study 2015' for easy identification. Study information sheets were posted to potential participants to inform them of the study prior to the first appointment.

Stage 2. **Patients seen on initial consultation clinics**

History and examination carried-out by a clinician, as part of normal routine. The following information was also collected:

1. Confirmation of consent of those who fulfilled the inclusion criteria.
2. Baseline anxiety level using MCDASf questionnaire (Appendix 11)
3. Baseline QoL level using COHIP-SF19 questionnaire (Appendix 12)
4. Clinicians involved in the subject patients' care during the initial consultation appointment completed the clinician questionnaire (Appendix 19), answering questions relating to their treatment plan and variables affecting their decisions for the patient.
5. Clinical records such as OPT radiograph, clinical photographs, and impressions for study models were obtained either on this initial appointment or in an arranged *collaborative prevention appointment*.

Stage 3. **Collaborative prevention appointment**

Children recruited in this study by definition had defective FPM, and therefore preventive care and support was considered to be beneficial. The primary investigator [HB] liaised with a Dental Therapist [SH] in seeing recruited patients during the *collaborative prevention appointment*.

1. Consent to participate in the study was reconfirmed, and patients were reminded they were free to withdraw from the study at any time and it would have no influence on their treatment.
2. Relevant prevention was provided to optimise dental health, which may include diet advice, oral hygiene instruction, fluoride treatment, fissure sealants, or temporary restorations as per clinician's prevention plan.
3. Alginate impressions for study models were taken by either the primary investigator [HB] or a Dental Therapist [SH]. Other missing clinical records such as clinical photographs and OPT radiographs were also taken, where indicated.

Stage 4. **Planned dental care delivered**

Dental treatment was provided for these patients as planned. Participating in this study had no influence on dental treatment decisions and plans.

Stage 5. **Patients on long-term review**

The intention is to follow-up these children when they are established in the permanent dentition. The cohort of patients would therefore be contacted for a future subsequent study and re-assessed after treatment completion with regards to their anxiety, QoL, and dental and orthodontic clinical features to assess the effects of the different treatment provided to those children and how that relates to the current treatment practices and UK Guidance. Patients were informed about this in a written and verbal form at the time of original consent and are free to not participate in future research activity at any time.

3 Study summary flowchart

A summary of the many variables collected in this study are presented in Figure 3-1, in the form of a flowchart.

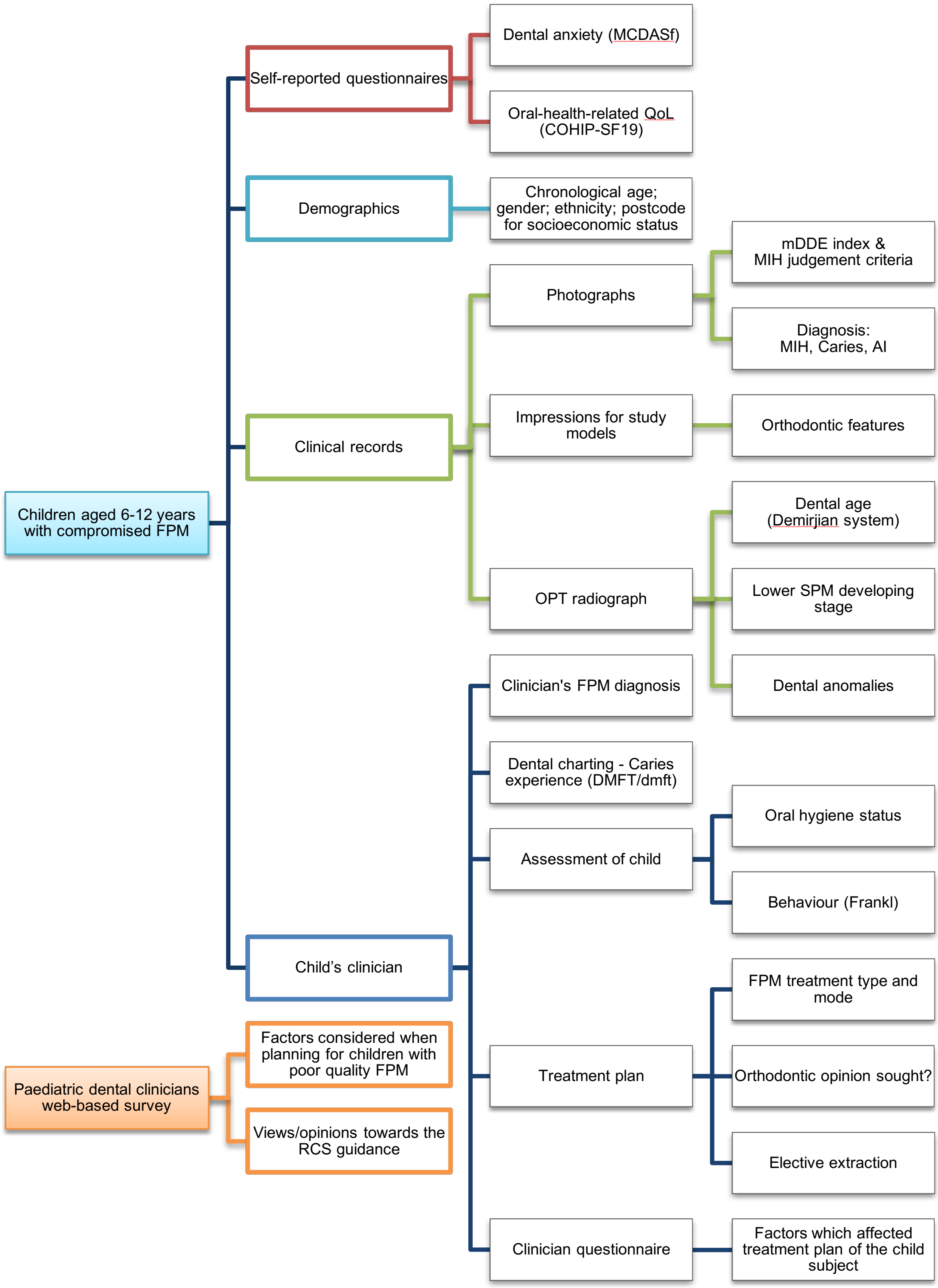


Figure 3-1: Study summary flowchart

4 Materials & Methods

4.1 Study Design

A descriptive observational study, prospectively recruited a cohort of children aged 6-12 years referred to the Leeds Dental Institute (LDI) for the management of defective FPM. This study investigated their presenting clinical dental and orthodontic features, dental anxiety, and oral health related QoL. This study also investigated the variables clinicians consider most important with treatment planning this cohort. There is an intention, as part of a follow-up study, to re-assess this cohort of children when established into the permanent dentition and evaluate the effects and outcome of the treatment interventions provided.

4.1.1 Ethical approval and assuring scientific quality

The study has been reviewed by the research supervisors [JS; SF; MD] and by the University of Leeds Dental Research Ethics Committee. Monthly meetings were held with the research supervisors [JS; SF] in line with the University of Leeds requirements and to address research progress to help insure high quality research outcomes.

Ethical approval was received from:

- NHS Research Ethic Committee (REC) Yorkshire and The Humber – Bradford Leeds (REC reference: 15/YH/0110) (Appendix 1)
- Leeds Teaching Hospitals NHS Trust Research & Innovation (LTHT R&I) (LTHT R&I Number: DT15/073) (Appendix 2)
- Integrated Research Application System (IRAS) ID number: 157962

Transparency of research is essential, and so the summary of this study was registered online in a publicly accessible database before subject recruitment, as per The World Medical Association Declaration of Helsinki. The summary is available via the following link (Appendix 3):

http://www.hra.nhs.uk/news/research-summaries/dental-and-orthodontic-features-of-fpm-with-mih-or-caries/

4.1.1.1 Confidentiality and Data Protection

Data Protection regulations were followed and any patient identifiable information was kept safe at the University of Leeds in a locked cupboard only accessible to the primary investigator [HB]. Research data was anonymised so that the participants could not be identified without the recruitment logbook containing patient details with their corresponding subject ID number. All data was kept secure in a password protected computer encrypted on the University of Leeds main server. The research subjects data were safeguarded at all times.

4.1.1.2 Consent

Several versions of the study information leaflets were provided, and that was tailored to the person's level of understanding and their role in the research. This included information sheets for the parents (Appendix 4), child age 9 -12 years (Appendix 5), child age 6-8 years (Appendix 6), and clinicians (Appendix 7). Upon confirming their understanding and their agreement to take part in the study, parents, child participants, and clinicians were free to sign their respective consents/ assents as shown in Appendix 8, Appendix 9, and Appendix 10, respectively.

4.1.2 Subject selection

Children subjects recruited in this study were derived from initial Consultation Clinics at the Paediatric Dentistry Department of the LDI. All recruited children had defective FPM and were referred to specialist care from a variety of sources including General Dental Practitioners and Specialist Paediatric Dentists. Potential subjects were previously identified following receipt of the original referrals at triage and patient information sheets were posted out prior to their initial consultation appointment.

4.1.3 Inclusion criteria

- Children aged 6-12 years referred to a specialist centre (LDI) requiring management of FPM affected by MIH, Dental Caries, or any other condition.
- Child and their parent/guardian were able to understand components of the study and give appropriate consent.
- Clinical photographs and OPT radiograph was required as a minimum dataset for the subjects. Impressions for study models were ideal for the full dataset, however, those without study models still had their data analysed and were not excluded.

4.1.4 Exclusion criteria

- Child and/or their patient/guardian not able to understand the study or not able to give consent.
- Subjects without clinical photographs, as this was essential to confirm diagnosis and assess severity of condition.
- Subjects without OPT radiographs, as this was essential to assess dental age and presence of anomalies in the developing dentition.

4.1.5 Subject groups

i. ***MIH group***

Subjects with MIH affecting FPM and/or incisors

ii. ***Caries group***

Subjects with dental caries affecting FPM, without FPM enamel defects

iii. ***AI group***

Subjects with defective FPM due to Amelogenesis Imperfecta diagnosis

4.2 Demographic data

4.2.1 Gender

Gender was identified from the participant’s health records as male or female.

4.2.2 Chronological age

Assessment of the chronological age was determined by subtracting the patient’s date of birth from the date of the initial assessment on their allocated consultation clinic at the LDI, coinciding with the date of recruitment into the study.

4.2.3 Ethnicity

Understanding participant’s ethnicity in this study may shed a light to understanding possible dental trends. Defining and measuring ethnicity is not straight forward, however, it is essential to remain consistent; so, the National Statistics standards for the classification of ethnic identification was adapted (Office for National Statistics, 2003). This guidance presented several standard classifications of ethnicity to meet a range of needs. The classification shown in Table 4-1 was used to categorise ethnicity for participants in this study.

Table 4-1: Presentation of ethnic groups for England and/or Wales, adapted by National Statistics (2003)

Presentation group:	***Combined categories:***
White	• White British • White Irish • Any other White background • All White groups
Mixed	• White and Black Caribbean • White and Black African • White and Asian • Any other Mixed background • All Mixed groups
Asian or Asian British	• Indian • Pakistani • Bangladeshi • Any other Asian background • All Asian groups
Black or Black British	• Black Caribbean • Black African • Other Black • All Black groups
Chinese or other ethnic group	• Chinese • Other ethnic group • All Chinese or Other ethnic groups
All ethnic groups (including White)	
Not stated	

4.2.4 Socioeconomic status

Assessment of socioeconomic status was made using the patient's UK home address post code according to the Index of Multiple Deprivation (IMD) developed by the Department for Communities and Local Government (DCLG, 2015). The IMD is an overall measurement of deprivation which is produced by combining seven domains with their respective weights, as listed in Table 4-2 (DCLG, 2015).

UK regions are ranked in 'deprivation quintiles' based on these variables, and each of the study patient's postcodes was linked to its relevant quintile. This method of socioeconomic status was also used by Balmer et al. (2012). This demographic was captured from the clinical records.

Table 4-2: Weights used in the Index of Multiple Deprivation (IMD)

Domain	Domain weight
Income Deprivation	22.5 %
Employment Deprivation	22.5 %
Health Deprivation and Disability	13.5 %
Education, Skills, and Training Deprivation	13.5 %
Barriers to Housing and Services	9.3 %
Crime	9.3 %
Living Environment Deprivation	9.3 %

From The English Indices of Deprivation (DCLG, 2015)

For practical reasons, an IMD online tool developed by National Perinatal Epidemiology Unit from the University of Oxford was used (NPEU, 2016). This tool allowed entering a participant's postcode in England, and an IMD score was produced (NPEU, 2016).

National and local government programs often use IMD to tackle deprivation and target funding to the most deprived areas. The IMD score is a measure of how local areas are ranked compared with others; thus allowing an understanding on where service commissioning is most needed (DCLG, 2015).

Table 4-3 below shows the IMD score within each quintile, where quintile 1 represents the 20% least deprived, and quintile 5 refers to the 20% of areas that are most deprived (NPEU, 2016).

Table 4-3: IMD score within quintile group

Quintile group	IMD score range
1	≤ 8.49 (***Least*** deprived)
2	8.5 – 13.79
3	13.8 – 21.35
4	21.36 – 34.17
5	≥ 34.18 (***Most*** deprived)

4.3 Baseline dental anxiety and quality of life

Previous studies have suggested MIH and caries experience in children may have an impact on their dental anxiety and oral-health related QoL. This study therefore assessed dental anxiety and oral-health related QoL using validated questionnaires at initial presentation, following both child and parent signed consent for study participation. Those questionnaires were completed either in the dental clinic with clinician's approval and/or in the waiting area.

4.3.1 Dental anxiety: MCDASf

Initial dental anxiety was measured at first consultation appointment using the faces version of the Modified Child Dental Anxiety Scale (MCDASf), shown in Appendix 11 (Howard & Freeman, 2007).

The MCDASf questionnaire consists of 8 questions relating to the dental setting scored from 1 (relaxed/not worried) to 5 (very worried). Total scores range from 8 to 40; and the cut off for 'anxious' is ≥ 26.

In this study, the primary investigator [HB] read out the questions to the child participant, and relevant scores were documented. This was done at the initial consultation visit at the LDI. When parents were present, they were instructed not to contribute to or influence any answers.

4.3.2 Quality of life: COHIP-SF19

The Child Oral Health Impact Profile- Short Form 19 (COHIP-SF19) (Broder et al., 2012) (Appendix 12) was used to assess QoL at first consultation appointment. It was shown to be a reliable and valid method for assessing oral-health-related QoL for all school aged children, and is shorter and more efficient method of assessment compared to the original COHIP (Broder & Wilson-Genderson, 2007).

The COHIP-SF19 is a self-reported questionnaire consisting of 19 items, of which 5 are under the 'Oral Health' subscale, 4 under the 'Functional Wellbeing' subscale, and 10 under the combined 'Social-Emotional Wellbeing' subscale. The scores for each item range from 0 (never) to 4 (Almost all the time); except the last two items, with 0 (Almost all the time) and 4 (Never).

In this study, the primary investigator [HB] explained the questionnaire and read out the items to the child participants, who answered them independently, without any parent/carer influence.

4.4 Clinical records collected

Participants and their guardians consented for additional clinical records to be taken for the purposes of this study. Every effort was made to ensure the collection of all the necessary clinical data from the participants. However, in cases where the child's anxiety or other reasons prevented collection of a complete dataset, that was taken into account and the participants were not excluded from this study for those reasons alone.

4.4.1 Clinical photographs

Clinical photographs of study participants were undertaken in order to record the initial clinical presentation, whilst reducing the participant's need to spend time in the dental clinic. They were taken by either of four professional clinical photographers at the LDI's Medical & Dental Illustration Department's photography studio [MC, ZK, CS, and EW]. The photographic views are based on the Institute of Medical Illustrators national guidelines for Orthodontic photography (Evans et al., 2008). All extra-oral images were taken against a blue background.

i. **Clinical photograph views:**

   Intra-oral views:

   - Two anterior views 1:2 with teeth in occlusion, and with anterior teeth apart (to show labial surfaces of upper and lower teeth).
   - Two buccal views 1:2 (right and left)
   - Two occlusal views at 45º angle 1:3 (upper and lower)

   Extra-oral views -in the natural head position:

   - Anterior view smiling 1:1.5
   - Anterior view relaxed facial muscles, not smiling 1:1.5
   - Right ¾ view 1:1.5
   - Right lateral view 1:1.5

   Total number of photographs per participant = 9

ii. **Camera information:**

   Clinical camera routinely used for patients in the Medical & Illustration department, with both flash and camera batteries changed before photographing each patient. This is to ensure consistency in flash and photograph quality. All clinical photographs were standardised with the following camera settings:

   - **1:1.5** f20 at 1/125th, ISO200, flash M1/4
   - **1:2** f20 at 1/125th, ISO200, flash M1/4
   - **1:3** f16 at 1/125th, ISO200, flash M1/4

Appendix 13 shows an example of a participant's photographic records for this study.

4.4.2 Dental impressions and orthodontic study models

Dental impressions of study participants were required to assess baseline orthodontic status at initial presentation and to be used as a basis for future follow-up of the cohort. Taking dental impressions is a common procedure in paediatric patients for many reasons including treatment planning and orthodontic treatment. A number of participants in this study required impressions for fabrication of sports guards and removable appliances.

Upper and lower dental impressions were taken by the primary investigator [HB] or a trained Dental Therapist [SH] using alginate impression material (XantALIGN® Select Alginate Impression Material, fast set) and standard impression trays. Bite registration was recorded using pink wax (Kemdent Anutex toughened dental modelling wax). Impressions were poured within 24 hours with white dental stone (John Winter & Co. Snow White Stone) to avoid dimensional changes. Two experienced senior lab technicians [DP and MF] were responsible for fabricating the orthodontic study models and trimming them to reproduce the patient's teeth as accurately as possible. The models were trimmed so that when the models are set on their heels, the patient's occlusion is reproduced.

All the study models were checked by the primary investigator [HB] and an experienced consultant orthodontist [JS] and occlusions were confirmed against corresponding clinical photographs. Necessary adjustments such as re-trimming were made as appropriate and re-checked at a later date. For dental casts that were regarded as low quality, every effort was made to re-take the impressions, where required.

4.4.3 OPT radiograph

The participant's OPT radiographs were assessed in order to determine dental age and the presence of any anomalies such as impacted or missing developing teeth. The decision to take an OPT radiograph was determined solely by the responsible clinician(s) to aid diagnosis and treatment-planning for the study participants. Some subjects had previous OPT radiographs, while others required OPT radiographs taken at the time of initial assessment.

4.5 Dental Age

Assessing maturity of a growing child is one factor to successful treatment planning, as growth could be utilised for improved orthodontic outcomes (Kansal & Singh, 2015). Chronological age is considered a poor indicator of maturity; and so, dental maturity was calculated to evaluate dental ages of subjects in this study. This was done using OPT radiographs and implementing the Demirjian's revised 7-teeth method (Demirjian & Goldstein, 1976). Demirjian's developmental stages of the permanent dentition are well-defined and are relatively easily identifiable (Demirjian et al., 1973).

4.5.1 Dental Age calibration

An interactive multimedia CD-ROM (Demirjian, 1994) containing tutorials on Demirjian's Dental Development stages, as well as training modules with a large database of dental radiographs, was utilised to calibrate the primary investigator [HB] for Dental Age assessment. There were difficulties in obtaining this multimedia software, as it was not available in other UK universities and the publishers ceased to exist. Access to the software was successfully obtained in collaboration with Josephine Stovall of the University of California Santa Cruz Library, following a formal visit.

4.5.2 Dental Age assessment

As per the Demirjian system (Demirjian et al., 1973) and later modified (Demirjian & Goldstein, 1976), the 7 left permanent mandibular teeth (M_2, M_1, PM_2, PM_1, C, I_2, I_1) were assessed and given a score of '0' for no calcification or one of 8 stages of calcification A to H (illustrated in Appendix 14 with criteria in Appendix 15). Crown formation is represented in stages A, B, and C; with completion of crown development in stage D. Root development is represented in stages E, F, and G. There is a separate classification system for girls and boys due to variability at which permanent teeth reach different stages of mineralisation.

For each of the rated 7 teeth, a self-weighted maturity score based on Demirjian's (1976) girls or boys maturity table was assigned (Appendix 16). The sum of the 7 rated teeth produces a total maturity score, which corresponds to Dental Age at the 50^{th} percentile of Demirjian's (1976) dental maturity percentiles (Appendix 17).

Examples of how Dental Age was calculated on a girl and boy subject, are shown in Figure 4-1 and Figure 4-2, respectively.

Dental age example 1:

Figure 4-1 shows a 10.2 year old girl with a maturity score of 78.1, which translates into a Dental Age of 8.1 in Demirjian's Girls Percentile Chart (Appendix 17). The Clinical Evaluation section of the Demirjian's multimedia software (1994) also calculates the dental age as shown below.

Tooth number	M_2	M_1	PM_2	PM_1	C	I_2	I_1	
Tooth stage	E	G	F	F	F	E	G	
Maturity score	11.7	12.5	12.3	14.3	10.0	5.3	12.0	**=78.1**

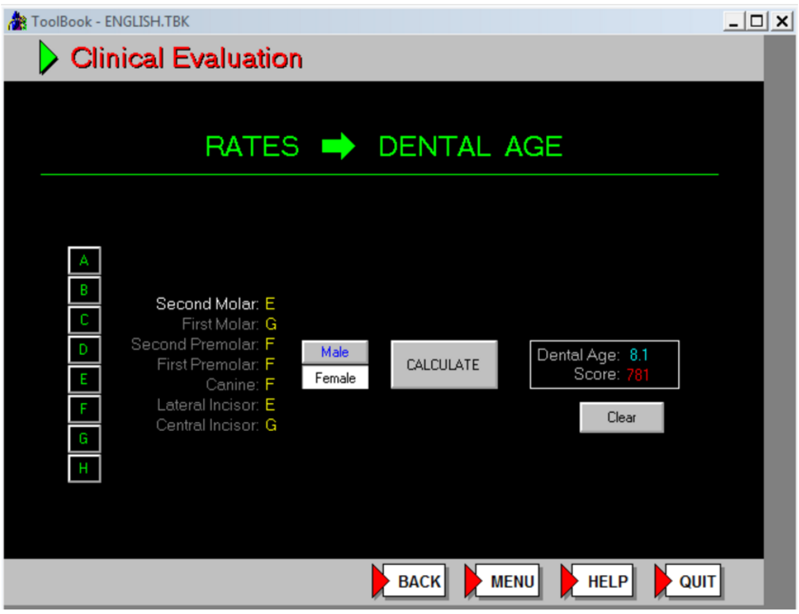
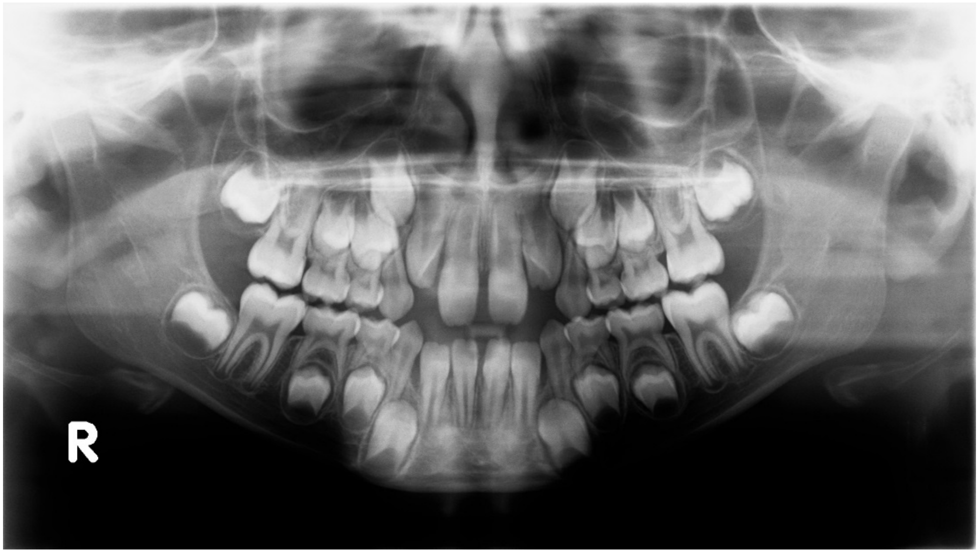


Figure 4-1: A girl (#042) with chronological age 10.2 and dental age 8.1 years

Dental age example 2:

Figure 4-2 shows an 8.7 year old boy with a dental age of 7.6; which was evaluated using his total maturity score of 62.8 in the Boys Dental Maturity conversion chart (Appendix 17) and the multimedia software (Demirjian, 1994).



Tooth number	M_2	M_1	PM_2	PM_1	C	I_2	I_1	
Tooth stage	D	G	D	D	D	F	G	
Maturity score	8.6	13.9	8.0	9.4	4.0	7.7	11.2	=**62.8**

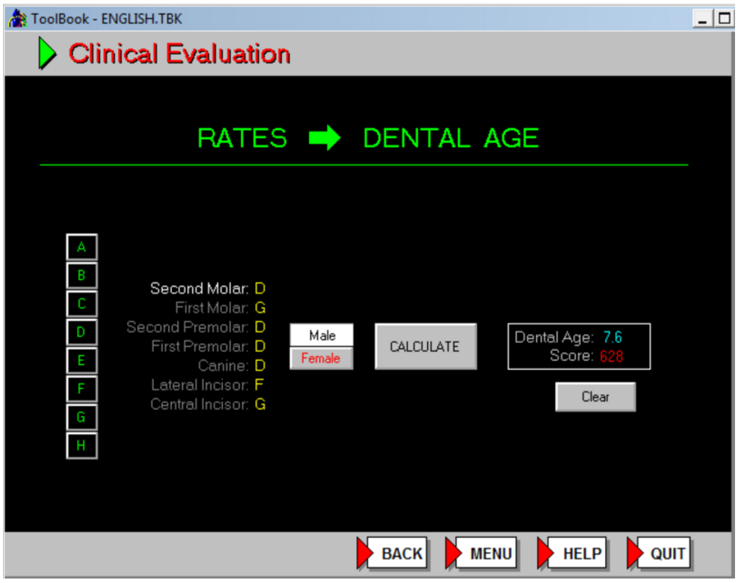


Figure 4-2: A boy (#105) with chronological age 8.7 and dental age 7.6 years

4.5.3 Developmentally absent teeth

Where a permanent tooth was developmentally absent or distorted and could not be rated, the contralateral on the right side of the mandible was rated instead, as there is a high degree of lateral symmetry (Demirjian & Goldstein, 1976; Demirjian et al., 1973).

Dental age estimation for individuals with bilaterally missing teeth remains unsolved (Flood, 2012). It would not have been beneficial to exclude children with bilateral missing premolars from Dental Age assessment for that reason alone. Therefore, Liversidge's (2010) table of median tooth formation stage by age was used to substitute the value for bilaterally missing premolars (Appendix 18).

4.6 Clinician's judgement and treatment planning

The clinician responsible for each individual subject patient's care at initial consultation appointment was asked to complete a paper-based questionnaire related to different aspects of each specific subject patient's diagnosis and treatment plan (Appendix 19). The questionnaire was piloted in a number consultation clinics prior to patient recruitment. Comments were obtained from the clinicians, and relevant amendments have been made over several versions of the questionnaire, and later finalised at version 4.

4.6.1 Clinician's position

The clinician was asked to name their dental position, which includes: Consultant, Specialist or Post-CCST, Postgraduate or Pre-CCST, and Dental Core Trainee.

4.6.2 Behaviour the dental setting

Clinicians rated the behaviour of their patients in the dental setting using Frankl's (1962) behaviour rating scale (Figure 4-3). All clinicians were familiar as this scale, as it is a standard way of assessing child dental behaviour in the Paediatric Dentistry Department at the LDI.

1. Definitely negative (- -)	• Refuses treatment • Forceful crying • Fearfulness, extreme negativism
2. Negative (-)	• Reluctant to accept treatment • Uncooperative behaviour
3. Positive (+)	• Acceptance of treatment • Cautious behaviour at times • Follows dentist's directions cooperatively
4. Definitely positive (++)	• Good rapport with dentist • Interest in dental procedure • Laughter and enjoyment

Figure 4-3: Frankl's (1962) **Behaviour Rating Scale**

4.6.3 Oral hygiene status

Overall oral hygiene of subject patients were assessed by their clinician at initial consultation appointment. Scoring categories were derived from the Simplified Oral Hygiene Index (Blue, 2017):

- Good oral hygiene
- Fair oral hygiene
- Poor oral hygiene

4.6.4 Symptoms from FPM

Clinicians were asked to note whether their subject patient has any complaints of pain, sensitivity, or any other symptoms specifically from the FPM.

4.6.5 Clinician's FPM diagnosis

Clinicians were asked to note the diagnosis of the subject patient's FPM, in their professional opinion. The diagnoses of all the subjects in this study were either MIH, Dental Caries, or AI.

4.6.6 FPM restorability/prognosis

Clinicians were asked to rate the restorability and prognosis of each of their subject patient's FPM (UR6, UL6, LL6, LR6) using the following categories:

i. ***Sound**- No restorative intervention required*

   This indicated that the FPM is sound or has an existing sound restoration.

ii. *Restorable with **Good** long-term prognosis*

   This indicates that the FPM has Caries lesion(s) or enamel breakdown, requiring restoration but has a good long term prognosis.

iii. *Restorable with **Questionable** long-term prognosis*

   This indicates that the FPM requires a restoration and has a good short-term, but questionable long-term prognosis.

iv. ***Non-Restorable** or has poor long term prognosis*

   This indicates that the FPM is either broken-down and non-restorable or could be temporised in the medium term, but essentially has a poor long term prognosis.

4.6.7 FPM agreed treatment plan

Clinicians were asked to reveal the agreed treatment plan for their subject patient's FPM, which was summarised in the following categories:

- Extraction of FPM
- Restoration of FPM
- Restoration and extraction of FPM
- Temporisation of FPM
- Review of FPM *(includes fissure sealants, but no operative intervention)*

4.6.8 Elective extractions of FPM

This study identified whether clinicians planned for any elective extractions of FPM in recruited subjects. This information was extrapolated from the clinician's assessment of FPM restorability/prognosis. When an FPM was evaluated by the clinician as *'sound'* or *'restorable with good long-term prognosis'* and planned for extraction, that FPM was regarded as an elective extraction.

Elective extractions of FPM were summarised in the following categories per subject patient:

- Elective extraction- compensate of upper FPM
- Elective extraction- compensate of lower FPM
- Elective extraction- compensate upper and lower FPM
- Elective extraction- balance contralateral FPM
- No elective extraction planned
- Not applicable *(no FPM extractions planned)*

4.6.9 Mode of treatment

Clinicians were asked to reveal what mode of treatment was agreed upon at the initial consultation visit for providing the discussed treatment plan for the subject patient:

- LA – Local Anaesthesia
- GA – General Anaesthesia
- IS – Inhalation Sedation
- Combination – combination of GA and any other mode

4.6.10 Factors influencing subject's treatment plan

Clinicians responsible for each individual subject patient's care at initial consultation were asked to note what factors influenced their treatment-planning decision specifically for that patient. This was an open-ended question to avoid leading the clinician towards any particular response in order to prevent unwanted bias. The open responses were challenging to analyse, as data coding was required before inputting responses into electronic data files. All responses were placed in relevant 25 categories, as shown below (Figure 4-4).

Clinical state of the FPM:

1. FPM severity or breakdown *(ie quality/quantity of remaining tooth structure)*
2. FPM restorability
3. FPM long term prognosis

Clinical signs & symptoms:

4. Presence of symptoms
5. Signs of pathology
6. Dental anomalies *(includes ectopic and infraoccluded teeth)*
7. Aesthetics

Orthodontic factors:

8. General orthodontic consideration
9. Occlusion *(includes incisor and molar relationship/ malocclusion)*
10. Crossbites/ openbites
11. Crowding
12. Skeletal pattern
13. Orthodontic opinion/plan

Age/Dental Age

14. Age
15. Dental age

Permanent dentition *(or developing dentition)*

16. Presence of developing teeth *(includes hypodontia)*
17. 7's development *(including root development and eruption)*
18. Presence of 8's

Oral health status

19. Caries risk
20. Oral hygiene & motivation

Patient factors

21. Patient behaviour/cooperation *(includes patient anxiety)*

Social factors

22. Social history *(includes dental attendance)*
23. Parent /child's wishes

Systemic health factors

24. Medical history

Treatment factors

25. Type or mode of treatment *(extraction/restoration/LA/GA/IS)*

Figure 4-4: Coding categories of factors influencing subject's treatment planning

4.6.11 Orthodontic opinion

Clinicians involved in the subject patient's care were asked whether or not an opinion was sought from an orthodontic specialist prior to finalising the treatment plan at this initial consultation appointment.

4.6.12 Time required to complete clinician questionnaire

Clinicians were also asked to state the number of minutes it took them to complete the paper-based questionnaire.

4.7 Dental caries experience

Presence of dental caries at baseline was recorded as DMFT and dmft indices for permanent and primary teeth respectively, according to the WHO criteria (2013). This was assessed using a combination of the dental records charting and clinical photographs.

DMFT = number of Decayed, Missing due to caries, and Filled teeth in the *permanent* dentition.

dmft = number of decayed, missing due to caries, and filled teeth in the *primary* dentition.

4.7.1 DMFT/dmft index

Components of the DMFT/dmft index (WHO, 2013):

- **D**: Decayed teeth

  Includes the following: carious teeth, filled teeth with recurrent decay, remaining root, defective filling with caries, temporary filling, and a filled tooth with another decayed surface. Initial lesions such as chalky spots and stained fissures are not considered in this component.
- **M**: Missing teeth due to caries

  The following should be excluded from this component: teeth extracted for reasons other than caries (ie orthodontic treatment, impaction, periodontal disease), un-erupted teeth, developmentally missing teeth, tooth avulsion due to trauma.
- **F**: Filled teeth due to caries.

  A tooth is included in this component if the present restoration(s) do not have recurrent caries and/or another carious surface. A tooth that has a crown restoration due to previous decay is included in this component. Teeth restored for reasons other than dental decay are not included in this component (ie. Trauma, enamel defects or for cosmetic purposes, bridge abutment, fissure sealants).

A tooth may only be recorded in one component: D, M, F, or sound. If a tooth has several restorations, it should be counted as one single filled tooth under component F. If a tooth has a restoration on a surface and caries on another surface, it should be regarded as a decayed tooth under component D. A tooth is considered erupted when the cusp tip of the occlusal surface or incisor edge is exposed. Supernumerary teeth are excluded in the DMFT index (WHO, 2013; Klein et al., 1938).

4.7.1.1 ‘Decayed’ component of DMFT and FPM posteruptive enamel breakdown

FPM with caries-free posteruptive breakdown were not included in the ‘Decayed’ component of DMFT, as it is not true dental caries (Petrou et al., 2014; WHO, 2013). It was difficult to distinguish between carious and caries-free breakdown; Therefore, hypomineralised FPM which have breakdown into dentine or secondary decay into dentine were included in the ‘decayed’ component of DMFT, as per previous MIH studies (Arrow, 2017; Americano et al., 2017).

4.7.1.2 ‘Missing’ component of dmft

The ‘missing’ component of dmft was not always straightforward to quantify, as previous dental treatment may not always be available or recorded in the patients’ dental records. It was therefore decided that if a child had had previous dental treatment and a primary incisor is missing earlier than the exfoliation window published by the AAPD (2015), and the permanent successor has not yet erupted, then it is scored as ‘missing’ (m) component of dmft. Best judgement was applied, which involved looking into previous patient records as well as using the contralateral for confirmation. The exfoliation windows of primary teeth are shown in Table 4-4.

Table 4-4: Exfoliation windows of primary teeth (AAPD, 2015)

	Maxillary	*Mandibular*
Primary central incisors	7-8 yrs	6-7 yrs
Primary lateral incisors	8-9 yrs	7-8 yrs
Primary canines	11-12 yrs	9-11 yrs
Primary first molars	9-11 yrs	10-12 yrs
Primary second molars	9-12 yrs	11-13 yrs

AAPD’s (2015) exfoliation charts were adapted by creating the dental charts shown in Table 4-5 to simplify quantifying the ‘missing’ component of dmft in cases with missing primary teeth and no evidence of eruption of permanent successor.

Table 4-5: Dental charts of primary teeth present according to age

Age	Primary teeth expected to be present	
6 yrs	E D C B A	A B C D E
	E D C B	B C D E
7 yrs	E D C B	B C D E
	E D C	C D E
8 yrs	E D C	C D E
	E D C	C D E
9 yrs	C	C
	E D	D E
10 yrs	C	C
	E	E

4.7.1.3 Calculation of DMFT/dmft

- Calculation for an individual:

  DMFT = D + M + F

- Calculation for a population:

  Mean DMFT = Total DMFT/ Total number individuals in the population

4.7.2 Dental Caries severity

Dental Caries severity is assessed in all participants in this study in the form of DMFT/dmft values. Dental Caries of FPM was further assessed in participants in this study diagnosed with Dental Caries alone without enamel defects (i.e. Caries-group)

4.7.2.1 DMFT/dmft Caries severity

DMFT and dmft scores were calculated separately in all participants in this study and dental caries severity was expressed based on WHO (2013) values:

- Caries-free 0 DMFT/dmft
- Low 1-2 DMFT/dmft
- Moderate 3-4 DMFT/dmft
- High ≥ 5 DMFT/dmft

4.7.2.2 FPM Caries severity

Children with defective FPM due to Dental Caries alone and no pre-existing enamel defect (i.e. Caries group) had each of their FPM (UR6, UL6, LL6, LR6) further assessed using the following severity categories:

- Sound
- Mild 1 surface Caries
- Moderate ≥ 2 surface Caries
- Severe Caries into pulp and/or remaining roots

FPM severity was also quantified by the total number of FPM affected with Dental Caries per child subject diagnosed with Dental Caries alone (Caries group).

4.8 Enamel defects

Enamel defects on FPM and permanent incisors was identified, evaluated and recorded according to the patient’s clinical photographs and quantified using the Modified Developmental Defects of Enamel index (mDDE index) shown in Figure 4-5 (Clarkson & O’Mullane, 1989).

MODIFIED DDE INDEX FOR USE IN GENERAL PURPOSE EPIDEMIOLOGICAL STUDIES

	Code
Normal	0
Demarcated opacities:	
white/cream	1
yellow/brown	2
Diffuse opacities:	
Diffuse - Lines	3
Diffuse - Patchy	4
Diffuse - Confluent	5
Confluent/patchy + staining + loss of enamel	6
Hypoplasia:	
Pits	7
Missing Enamel	8
Any other defects	9
Extent of Defect	
Normal	0
<1/3	1
at least 1/3 < 2/3	2
at least 2/3	3

TABLE 8
MODIFIED DDE INDEX FOR USE IN SCREENING SURVEYS

	Code
Normal	0
Demarcated opacity	1
Diffuse opacity	2
Hypoplasia	3
Other defects	4

Figure 4-5: mDDE Index (Clarkson & O'Mullane, 1989)

The main investigator [HB] was calibrated with support of a senior academic [RB], trained and experienced in the use of the mDDE index. Calibration was done in a similar way to the calibration method of the examiners in Balmer et al's (2012) multicentre study. This involved training slides of 50 tooth surfaces with a variety of conditions, which acted as gold standards to test against for examiner calibration.

The mDDE index was used specifically to note the presence or absence of demarcated opacities on FPM and permanent incisors, aiding in confirming MIH diagnosis.

4.9 MIH diagnosis

4.9.1 MIH diagnosis using mDDE index

For subjects recruited in this study, a diagnosis of MIH was made using the mDDE index (Clarkson & O'Mullane, 1989) and the criteria described by Balmer et al. (2012), where there is a demarcated enamel defect present in at least one surface of a FPM. In cases where one or more FPM were absent, a diagnosis of MIH was judged if any demarcated defects were present on any permanent incisors.

4.9.2 MIH diagnosis using EAPD judgement criteria for MIH

EAPD's MIH judgement criteria proposed by Weerheijm et al (2003) was adapted in this current study, as it is a widely used criteria in MIH studies. It advises that examination for MIH should ideally be performed clinically on wet teeth in a child 8 years of age, where all FPM and permanent incisors are expected to be erupted at this age (Weerheijm et al., 2003). For the purposes of this study, subject patient's high-quality clinical photographs were assessed.

Definitions of the MIH judgement criteria (Weerheijm et al., 2003):

- ***Demarcated Opacity*** **(DO):** A demarcated defect involving an alteration in the translucency of enamel, variable in degree. The defective enamel is of normal thickness with a smooth surface and can be white, yellow, or brown in colour.
- ***Posteruptive Enamel Breakdown*** **(PEB):** A defect that indicates deficiency of the surface after eruption of the tooth. Loss of initially formed surface enamel after tooth eruption. The loss if often associated with a pre-existing demarcated opacity.
- ***Atypical restoration*** **or cavity (AT):** The size and shape of the restoration do not conform to the caries picture. Frequently, an opacity can be noticed at the border of the restorations. In incisors a buccal restoration can be noticed not related to trauma.
- ***Extracted due to MIH*** **(E-MIH):** Absence of a FPM should be related to the other teeth of the dentition. Teeth suspected for extraction due to MIH are: opacities or atypical restorations in other FPM combined with absence of a FPM. Also, the absence of FPM in a sound dentition In combination with demarcated opacities on the incisors is suspected for MIH. It is not likely that incisors will be extracted due to MIH.
- ***Unerupted*** **(UE):** The FPM or the incisor to be examined are not yet erupted.

Other dental enamel defects such as hypoplasia, diffuse opacities, white spot lesions, erosion, fluorosis, AI defects, and white cuspal and marginal ridges were not judged as MIH (Weerheijm et al., 2003).

4.9.3 Severely broken-down FPM and/or retained roots (RR)

In patients where there was MIH diagnosis according to the mDDE index and/or EAPD judgement criteria (ie. MIH group), presence of an FPM affected by a large carious lesion and/or RR was regarded as severe post eruptive enamel breakdown (PEB). Therefore, PEB was assumed in patients with large carious lesion or RR of FPM if there was evidence of demarcated opacities on remaining FPM and/or permanent incisors, suggesting MIH diagnosis (Weerheijm et al., 2003).

4.9.4 MIH severity

Severity of MIH was rated in subjects diagnosed with MIH. There are a variety of severity scales described in the literature, however, the severity criteria most commonly used is that proposed by Leppaniemi et al (2001) and were clearly described by Da Costa-Silva et al (2011):

1. **Mild MIH**: demarcated opacities with no structural loss or atypical restorations
2. **Moderate MIH**: Enamel opacities associated with PEB limited to enamel
3. **Severe MIH**: Hypomineralised lesions associated with loss of dentinal structure affecting enamel and dentine, and/or atypical restorations replacing affected hard tissue.

4.10 Orthodontic assessment

Orthodontic assessment was done using a combination of the participants orthodontic study models and clinical photographs for intra-oral and extra-oral assessment.

4.10.1 Dental development stage

The patients in this study range from a chronological age of 6 to 12; and therefore have varying stages of dental development. In order to better analyse their dentitions orthodontically, they have been placed in the following categories and analysed according to their developmental stage:

a)	**Early mixed dentition**	Incisors erupting
b)	**Intermediate mixed dentition**	Incisors fully erupted
c)	**Adolescent dentition**	Canines and premolars fully erupted

Dental stages adapted from Bjork et al. (1964)

4.10.2 Index of Orthodontic Treatment Need (IOTN)

An orthodontic treatment need index such as IOTN identifies patients in need of orthodontic treatment and prioritises them according to their treatment need (Tang & Wei, 1993). The IOTN is one of the commonly used orthodontic indices and can be used on both adults and children. It comprises of two separately-recorded components: the Dental Health Component (DHC) developed in Cardiff (Evans & Shaw, 1987) and the Aesthetic Component (AC), developed in Manchester (Brook & Shaw, 1989).

i. **Dental Health Component (DHC)**

The DHC has five grades of orthodontic need ranging from 5 'very great need' 4 'great need', 3 'borderline need', 2 'little need' to 1 'no need'. A hierarchal scale was used to record the occlusal traits in the order of severity in descending order as follows:

M- Missing teeth	5i ,5h, 4h,
O- Overjet/reverse overjet	5a, 4a, 3a, 2a / 5m, 4m, 4b, 3b, 2b
C- Crossbite	4c, 3c, 2c
D- Displacement	4d, 3d, 2d
O- Overbite/Open bite	4f, 3f, 2f / 4e, 3e, 2e

Figure 4-6: IOTN Hierarchal Scale (Brook & Shaw, 1989)

A DHC grade is therefore given according to the worst occlusal trait following the 'MOCDO' acronym, using the IOTN hierarchal scale in descending order. Figure 4-7 below shows a list of deviant occlusal traits.

a	Overjet.	i	Impeded eruption of teeth
b	Reverse overjet with no masticatory or speech problems.	m	Reverse overjet with masticatory or speech problems.
c	Crossbite.	l	Posterior lingual crossbite.
d	Displacement of contact points.	p	Defects in cleft lip and palate.
e	Openbite.	s	Submerged primary teeth.
f	Deep bite (overbite).	t	Partially erupted teeth, tipped and impacted against adjacent teeth.
g	Good occlusion.		
h	Hypodontia.	x	Presence of supernumerary teeth.

Figure 4-7: IOTN occlusal traits

An IOTN ruler, as show in Figure 4-8, was used to aid in DHC assessment.

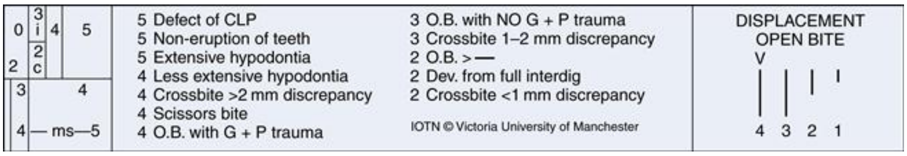


Figure 4-8: The IOTN ruler based on Brook and Shaw (1989)

As the dental study models were assessed with the absence of clinical information, the dental cast protocol described by Richmond (2008) was used. This assumes the worst case scenario. For example, presence of a crossbite was recorded as 4c assuming the worst displacement, rather than 2c or 3c.

ii. **Aesthetic Component (AC)**

The AC of the IOTN consists of a series of photographs illustrating a 10-point scale rating dental attractiveness on a scale of 1, most attractive to 10, least attractive. This scale is based on the original SCAN scale by developed in Cardiff by Evans and Shaw (1987). A grey scale version of the photographs can be used to assess aesthetics for dental casts (Richmond, 2008).

AC of IOTN was not assessed in this study, as it rates aesthetic attractiveness on permanent dentition, and most children in this study are in the mixed dentition.

4.10.3 PAR and ICON indices

PAR (Peer Assessment Rating) and ICON (Index of Complexity and Orthodontic Treatment Need) are orthodontic indices that allow us to quantify the severity of the orthodontic presentation and monitor the outcome of orthodontic treatment. Both indices can be assessed using patient’s dental study casts.

PAR is an objective numeric score that records the outcome of orthodontic changes in terms of occlusal changes. Assessment of pre and post treatment dental study casts gives weighted accumulative scores, indicating extent of deviation from normal functioning and degree of change/improvement after treatment. (Richmond et al., 1992).

ICON measures both treatment need and outcome of treatment and is based on both the IOTN and PAR indices. It combines five occlusal traits (IOTN aesthetic component, crossbite, upper arch crowding and spacing, buccal segment antero-posterior relationships, and anterior vertical relationship) with different weightings and a numeric score to determine treatment need, treatment complexity, and improvement resulting from treatment (Daniels & Richmond, 2000).

Certain elements of malocclusion are not evaluated in detail in IOTN. It was therefore decided to incorporate some components of PAR and ICON to categorise severity of overbite, centreline coincidence, and crossbites; as described in the sections below.

4.10.4 Dental crowding

Crowding is an important aspect of a malocclusion, and therefore requires assessment (Kirschen et al., 2000). Crowding of upper and lower arches in this present study was analysed according to the dental development stage of participants.

i. **Permanent dentition, with premolars erupted – crowding**

Crowding in the permanent dentition was assessed according to IOTN. Displacement of contact points (d) corresponds to crowding, and severity was graded according to need for orthodontic treatment, where 4 is great need and 2 is little need:

Severe crowding (4 d): displacement of teeth > 4mm
Moderate crowding (3 d): displacement of teeth > 2mm but to < 4mm
Mild crowding (2 d): displacement of teeth > 1 mm but < 2mm

ii. **Mixed dentition, with premolars not yet erupted – predicted crowding**

In the mixed dentition, crowding was assessed based on impeded eruption, and labelled as ‘predicted crowding’:

Predicted crowding: insufficient space for tooth eruption
No predicted crowding: sufficient space for tooth eruption

When there is insufficient space for a tooth to erupt, it is considered as impeded (Richmond, 2008). This was measured in the mixed dentition by measuring the distance from the mesial contact point of the FPM to the distal contact point of the lateral incisor and using average mesio-distal widths to calculate space availability. If the distance is less than 18 mm in the upper arch or 17 mm in the lower arch, then there is insufficient space for tooth eruption and is considered impacted, and therefore crowding is predicted. This method has been described for use in both IOTN and PAR scoring (Richmond, 2008; Richmond et al., 1992).

The distances were measured with the aid of a digital calliper (Mesrtra®, calibrated with 1/100th mm precision) on right and left sides of both upper and lower arches. Crowding in the mixed dentition was categorised as to whether there is or is not impaction, using the method described by Richmond (2008) and Richmond et al. (1992), as per Figure 4-9 below:

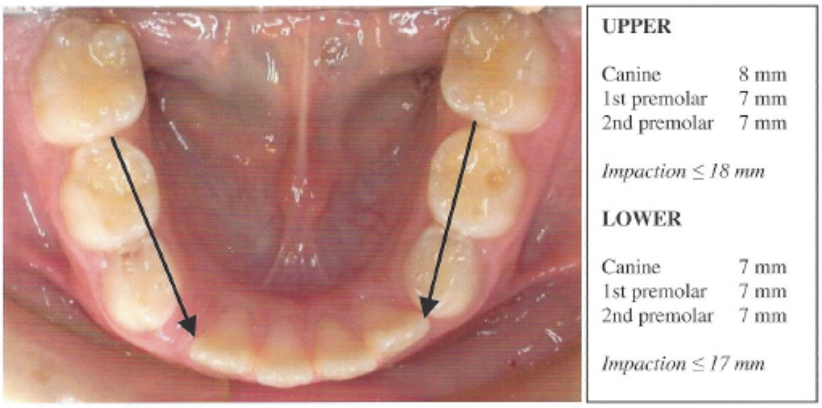


Figure 4-9: Crowding in the mixed dentition using average mesio-distal widths (Richmond, 2008)

4.10.5 Assessment of occlusion/ recording of malocclusions

The parameters of occlusion in the sagittal, vertical, and transverse planes were measured, recorded, and quantified using the methods described below. An orthodontic assessment sheet was developed, piloted and used to aid recording of these measurements (Appendix 21).

Sagittal plane (antero-posterior)	• Skeletal pattern • Molar relationship • Incisor relationship • Overjet, reverse overjet
Vertical plane	• Overbite • Anterior Openbite • Posterior Openbite
Transverse plane	• Centreline assessment • Anterior crossbite • Posterior crossbite
Other orthodontic parameters	• Dental crowding • Index of Orthodontic Treatment Need (IOTN)

1) Skeletal pattern:

Skeletal pattern was assessed using the lateral extra-oral views from the participants' clinical photographs. The antero-posterior dimension was assessed in order to relate the position of the mandible to the maxilla and the relationship of these bones to the cranial base. The 'zero meridian' line was used as a guide (Gonzalex-Ulloa, 1962). This line represents the anterior limit of the cranial base and is a vertical line drawn through soft tissue nasion in the natural head position (Gill & Naini, 2011). Another way to describe this 'zero meridian line' is that it can be achieved by mentally dropping a true vertical line down from the bridge of the nose. The upper lip should rest on or slightly in front of this line and the chin slightly behind. This is illustrated in Figure 4-10.

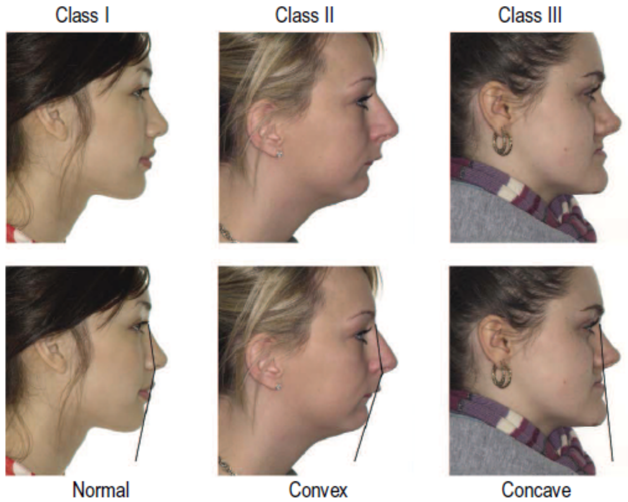


Figure 4-10: Zero meridian line (Cobourne & DiBiase, 2010)

Skeletal Class I: the mandible (lower jaw) lies 2-4mm posterior to the maxilla (upper jaw).
Skeletal Class II: the mandible lies retrusive relative to the maxilla (>4mm behind the maxilla). The profile is convex.
Skeletal Class III: the maxilla is retrusive relative to the mandible (the mandible is <2mm behind the maxilla). The profile is concave.
(Cobourne & DiBiase, 2010)

2) Molar relationship:

Right and left relationships were classified based on Angle's (1899) classification of molar relationship.

Class I: The mesiobuccal cusp of the maxillary first molar occluding in line with the buccal groove of the mandibular first molar i.e. the maxillary first molar is slightly posteriorly positioned relative to the mandibular first molar.
Class II: The mesiobuccal cusp of the maxillary first molar occluding anterior to the buccal groove of the mandibular first molar i.e. the maxillary first molar is in line with or anteriorly positioned relative to the mandibular first molar.
Class III: The mesiobuccal cusp of the maxillary first molar occluding posterior to the buccal groove of the mandibular first molar i.e. the maxillary first molar is severely posteriorly positioned relative to the mandibular first molar.

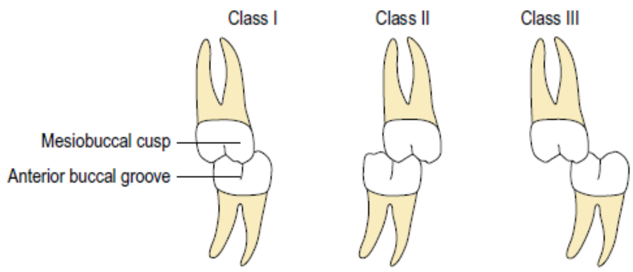


Figure 4-11: Angle's (1899) **molar classification** (Cobourne & DiBiase, 2010)

3) **Incisor relationship:**

The incisor relationship was classified according to the British Standard Institute (1983):

Class I: the lower incisor tips occlude or lie below the cingulum plateau of the upper incisors.
Class II Division 1: the lower incisor tips occlude or lie posterior to the cingulum plateau of the upper incisors. The overjet is increased with upright or proclined upper incisors.
Class II Division 2: the lower incisor tips occlude or lie posterior to the cingulum plateau of the upper incisors. The upper incisors are retroclined, with a normal or occasionally increased overjet.
Class III: the lower incisor tips occlude with or lie anterior to the cingulum plateau of the upper incisors.

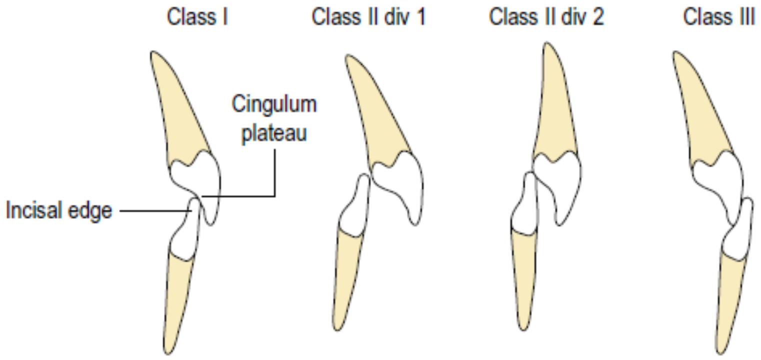


Figure 4-12: BSI (1983) **incisor classification** (Cobourne & DiBiase, 2010)

4) Overjet (a), reverse overjet (b):

Overjet, reverse overjet and overbite measurements were made using a clear ruler accurate up to 0.5 mm and implementing the method proposed by Brunelle et al. (1996).

Overjet was measured in millimetres from the incisal edge of the most prominent upper incisor to the labial surface of the lower incisors. It was recorded as per IOTN occlusal trait ‘a’ using the below severity categories:

- **No increased overjet**
- **Mild overjet** >3.5mm but ≤ 6mm
  (*Incompetent lips* IOTN grade 3; *competent lips* IOTN grade 2)
- **Moderate overjet** > 6mm but ≤ 9mm (IOTN grade 4)
- **Severe overjet** > 9mm (IOTN grade 5)

Reverse overjet has IOTN occlusal trait ‘b’ and the below severity categories were used. The occlusal trait ‘m’ was not used, as this refers to reverse overjet with masticatory or speech problems; and this is not possible to assess using the study models alone.

- **No reverse overjet**
- **Mild reverse overjet** > 0mm but ≤ 1mm (IOTN grade 2)
- **Moderate reverse overjet** > 1mm but ≤ 3.5mm (IOTN grade 3)
- **Severe reverse overjet** > 3.5mm (IOTN grade 4)

5) Overbite (f):

Overbite relates to any of the lateral or central incisors, where the largest vertical discrepancy was measured in millimetres using a clear ruler. It has the

IOTN occlusal trait ‘f’ and categorised according to the severities outlined by a combination of ICON and IOTN.

- **Decreased** <1/3 coverage of lower incisor (as per ICON)
- **Average** >1/3 but up to 2/3 of lower incisor (as per ICON)
- **Increased** >2/3 of lower incisor (as per ICON) or >3.5mm (as per IOTN)

6) Anterior openbite (e):

Presence of an anterior openbite was recorded and measured in millimetres from the study models using a clear ruler. Severity was assessed according to the IOTN:

- **No openbite**
- **Mild openbite** > 1mm but < 2mm (IOTN grade 2)
- **Moderate openbite** > 2 mm but < 4 mm (IOTN grade 3)
- **Severe openbite** > 4 mm (IOTN grade 4)

7) Posterior openbite (e):

Presence of posterior openbite was recorded and measured in millimetres from the study models using a clear ruler. Severity was assessed as per the IOTN:

- **No openbite**
- **Mild openbite** < 1mm but < 2mm (IOTN grade 2)
- **Moderate openbite** > 2 mm but < 4 mm (IOTN grade 3)
- **Severe openbite** > 4 mm (IOTN grade 4)

8) Centreline assessment:

Deviation of upper and lower arch midlines were measured to the nearest 0.5mm using a clear ruler. The upper centreline is the midpoint between the two upper central incisors; and the lower centreline is the midpoint between the two lower central incisors (Summers, 1971).

Where a central incisor is missing, an estimated midpoint according to size and position of the contralateral was used. Deviations to the right or left could not be assessed, as measurements were made directly on dental casts and patient’s clinical facial features could be taken into account.

Severity of centreline deviation was quantified as described in PAR, using the following categories:

- **0 -** Coincident and up to ¼ width of the lower incisor
- **1 -** ¼ to ½ width of the lower incisor

- **2 -** Greater than ½ width of the lower incisor

9) Anterior and posterior crossbite (c)

Crossbites were assessed by noting the location of their presence, ie. anteriorly and/or posteriorly, as per ICON (Daniels & Richmond, 2000).

An anterior crossbite was assessed from canine to canine when an upper anterior tooth occludes lingual to a lower tooth. Presence and absence of an anterior crossbite was recorded; and whether it involves a single tooth or multiple teeth.

- **No anterior crossbite**
- Anterior crossbite involving a **single tooth** or **multiple teeth**
- Anterior crossbite involving **permanent** or **primary** teeth

Posterior crossbites were assessed on premolars and molars and recorded when a lower posterior tooth is lingually placed with respect to an upper tooth. Posterior crossbites were further categorised as to whether it is bilateral or unilateral, and involving permanent or primary teeth.

- **No posterior crossbite**
- Posterior crossbite involving a **single tooth** or **multiple** teeth
- Posterior crossbite Involving **permanent** or **primary** teeth
- **Unilateral** or **bilateral** posterior crossbite

4.11 Web-based survey - Paediatric clinicians

A web-based survey to investigate FPM treatment planning decisions and awareness of the Royal College guidance on FPM extractions was developed, piloted and distributed via e-mail to clinicians involved in treating Paediatric dental patients in the Yorkshire and Humber. This involved sending an invitation to Paediatric clinicians in the LDI and the Yorkshire and Humber Paediatric Clinical Network group in November 2015. Several subsequent reminder emails were also sent a month apart. Recipients of the email invitations included Paediatric Dentistry Consultants, Specialists, Postgraduates, and Dental Core Trainees. Appendix 22 shows the invitation page of the web-based survey.

4.12 Statistical methods

4.12.1 Descriptive statistics

Data was initially digitised into a Microsoft Office Excel 2013 spreadsheet, and later entered into IBM SPSS Statistics for statistical analysis (SPSS, version 23, Chicago, IL). Descriptive statistics was performed on categorical data as frequencies, percentages, or proportions. Numerical data was summarised as means and standard deviations. Intra-rater reliability was also calculated using measurements of 26 randomly selected subjects via random.org (i.e. 25% of the total 105 subject in this study); using Cohen's kappa (κ) for categorical data or Interclass Correlation Coefficient (ICC) for continuous numerical data.

The level of significance was set at 5% ($p < 0.05$).

4.12.2 Data analysis – Group differences

For group differences between dichotomous (eg. yes/no; MIH/Caries) and non-normally distributed continuous numerical data, Mann-Whitney U tests were used.

For group differences between multinomial (eg. MIH/Caries/AI) and normally-distributed continuous numerical data, One-way ANOVA was used. When the data was not normally distributed, Kruskstal-Wallis H test was used as a non-parametric alternative.

4.12.3 Data analysis – Associations and correlations

Relationships between two continuous numerical variables were tested using Pearson's product-moment correlation for normally distributed data (eg. total anxiety score with chronological age). When the data was not normally distributed or the relationship was monotonic (rather than linear), Spearman's rank-order correlation was used as a non-parametric alternative.

Point-bisceral correlation was used to determine relationship between a dichotomous (e.g. yes/no) variable and a numerical variable (eg. number of teeth affected).

Eta (η) correlation coefficient was used to determine the association between a multinomial (e.g. agreed plan) and a continuous variable (e.g. chronological age).

Chi square test of independence was used to find the associated between two multinomial variables. When the minimum sample per group was not met, Fisher's exact test was used as an alternative (e.g. oral hygiene and agreed treatment plan).

5 Results

5.1 Clinicians recruited in the study

A total of 25 Paediatric dental clinicians consented to take part in this study, of which none refused to participate. These included 2 consultants, 4 specialists, and 20 postgraduates or pre-CCST. Postgraduates/ pre-CCST were supervised by a consultant or specialist in Paediatric Dentistry. The children in this study (n=105) were examined by the proportion of clinicians demonstrated in Figure 5-1.

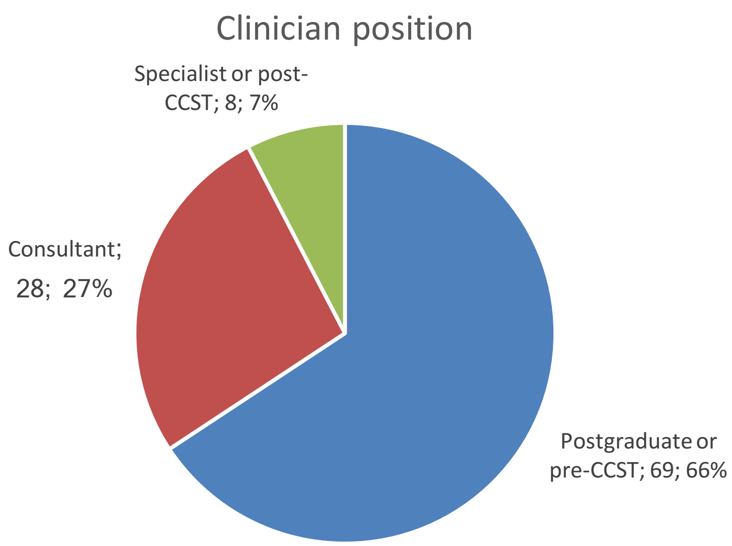


Figure 5-1: Proportion of clinicians (n= 25) who examined the children in this study (n=105)

5.2 Children recruited in the study

Over a period of 13 months (April 2015 to May 2016), the primary investigator [HB] attended 101 consultation clinics, of which 83 clinics had patients who fulfilled the inclusion criteria of the study. Of the 148 children who were approached, 115 consented to take part in the study.

Some children's clinicians did not justify a radiographic exposure of an OPT, as it would not have altered their management (n=4), while other children had missing clinical photographs due to time constraints or due to having FPM dental treatment before photographs were taken (n=6). Those children were therefore excluded from the study.

The final number of subjects in this study was 105 (MIH group 82, Caries group 20, AI group 3), as outlined in the flowchart in Figure 5-2.

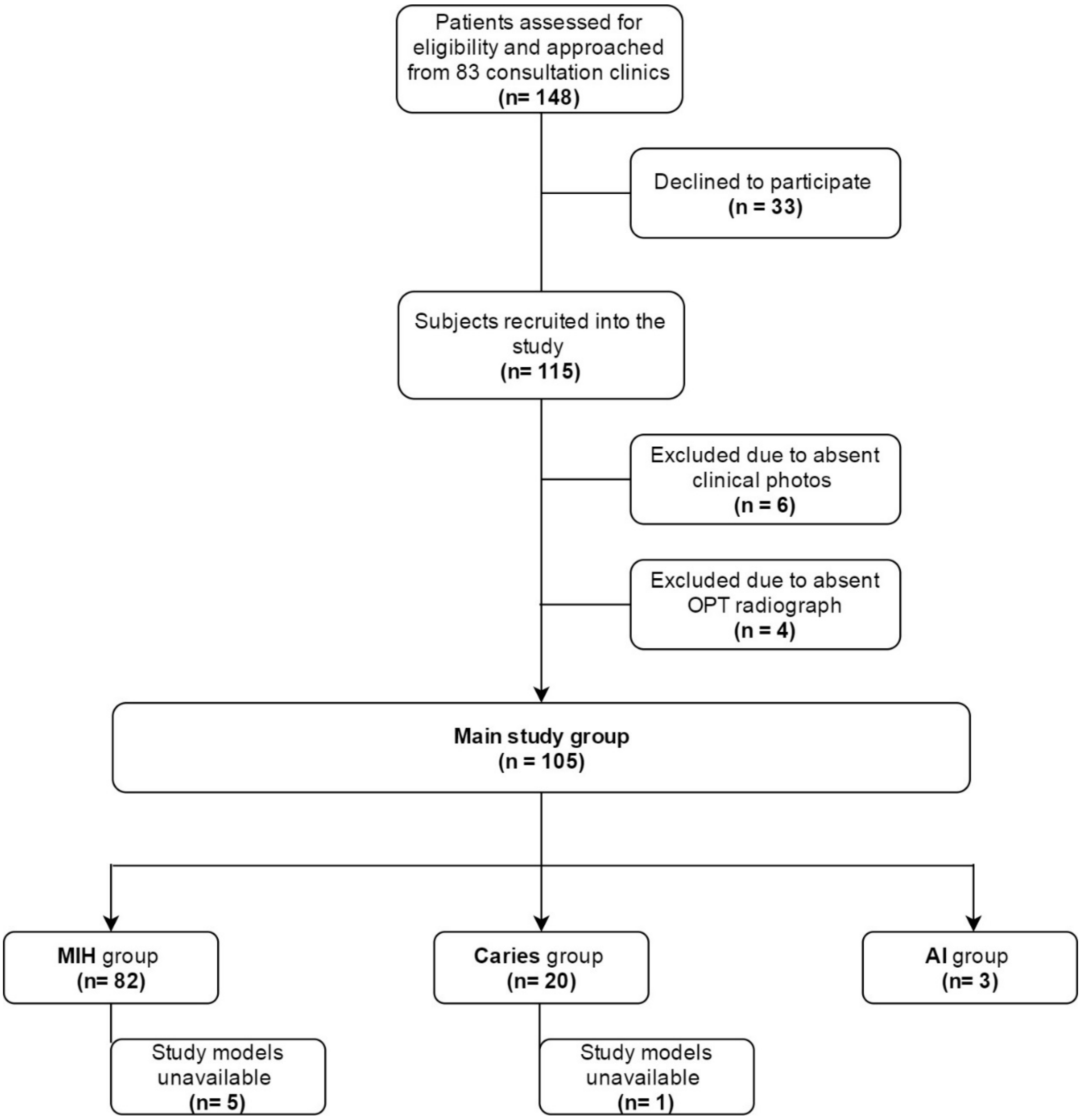


Figure 5-2: Flowchart of recruited subjects

5.3 Diagnosis

The diagnosis of children in this study was noted by the clinicians involved in the child's care. The primary investigator [HB] assessed clinical photos of all the children in this study, independent of the clinician's diagnosis. A diagnosis of MIH was given if there was a demarcated enamel defect in at least one FPM using the mDDE index (Clarkson & O'Mullane, 1989), and/or if any of the EAPD (2003) MIH judgement criteria was present: DO, PEB, AT, E-MIH, UE.

5.3.1 Agreement between clinician's diagnosis and diagnosis as assessed retrospectively by the primary investigator

Agreement between the diagnosis reported by the clinician in the patient's notes and diagnosis assessed by the primary investigator [HB] using clinical photographs and the mDDE index was assessed using Cohen's kappa (κ).

The clinicians and primary investigator agreed on 75 MIH, 20 Caries, and 3 AI diagnoses. In 7 cases, there was a difference between the diagnosis recorded by the examining clinician and the diagnosis subsequently considered to be correct by the primary investigator. In each instance, the examining clinicians diagnosed caries-only, whilst the primary investigator diagnosed each as having MIH. There was very good agreement between the diagnosis made by the examining clinicians and the diagnosis considered to be correct by the primary investigator, $\kappa = .830$ (95% CI, .709 to .951), $p < .0005$.

Figure 5-3 shows an example of a child (#070) diagnosed as having Caries in the UL6 by the clinician. However, inspection of the clinical photos reveals clear presence of an atypical cavity pattern of the mesio-palatal cusp of the UL6, in which a diagnosis of MIH was given.

Figure 5-3: A girl (#070) with atypical cavity pattern of the UL6, diagnosed as caries by the clinician

5.4 Demographic data

5.4.1 Gender

There were almost equal numbers of male (n=53) and female (n=52) children recruited into this study. The distribution of MIH, Caries, and AI diagnoses within the genders was similar, as seen in Figure 5-4.

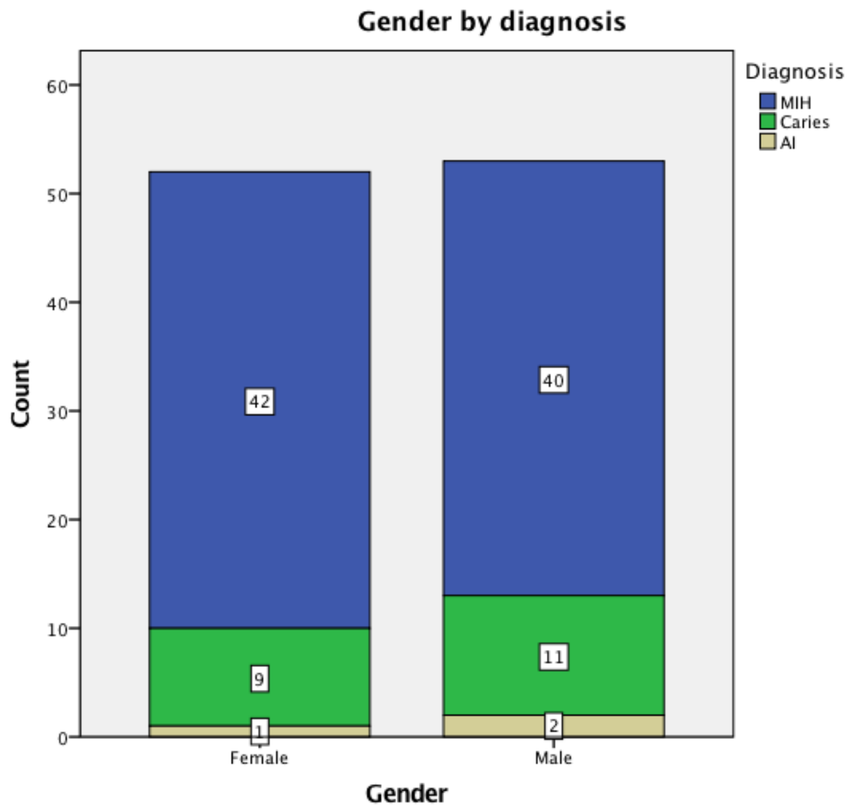


Figure 5-4: Distribution of gender by diagnosis

5.4.2 Chronological age

Chronological age was calculated using the date of initial assessment/recruitment and the date of birth. Children's ages ranged from 6.5 to 12.8 years with a mean of 9.0 ± 1.5 years. Chronologic age was normally distributed for both males and females, as assessed by Shapiro-Wilk's test ($p>0.05$).

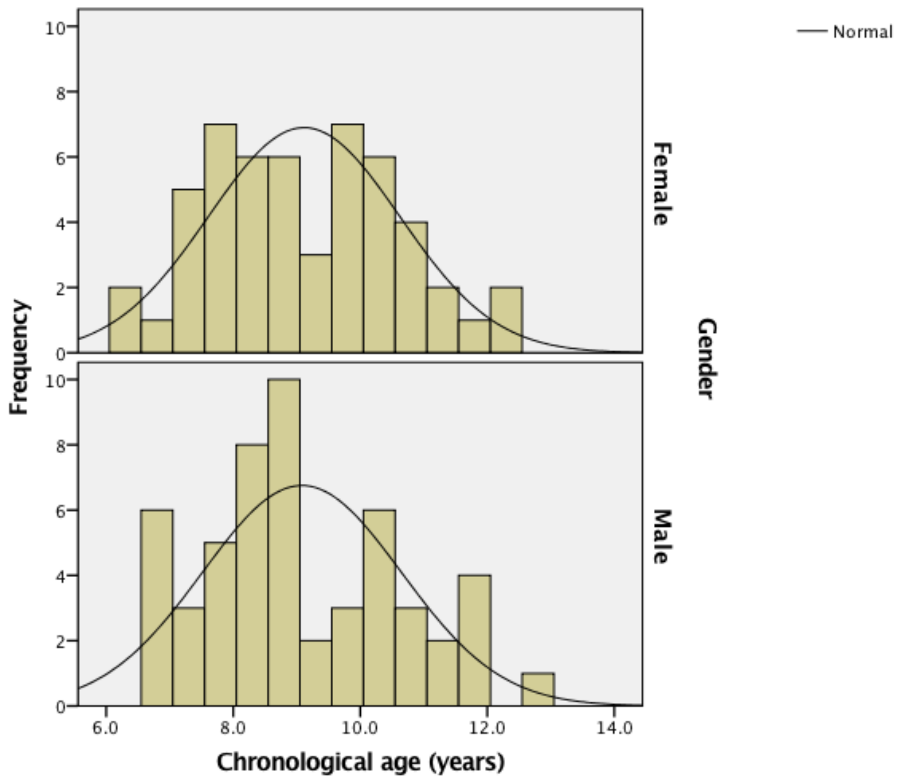


Figure 5-5: Distribution of chronological age of children in this study, by gender

5.4.3 Ethnicity

The majority (82.9%) of the study participants were of White British, Irish or any other White background (n= 87). Other ethnicities included Asian British or any other Asian background (7; 6.7%), followed by Mixed ethnicities (5; 4.8%), Black British or any other Black background (4; 3.8%), and Chinese or any other ethnic group (2; 1.9%).

5.4.3.1 Ethnicity and diagnosis

Distribution of ethnicity groups within children diagnosed with MIH, Caries, and AI is shown in Figure 5-6. There was no statistically significant differences in proportions of ethnicities in MIH, Caries, and AI children, as tested with Fisher's exact test, p=.259.

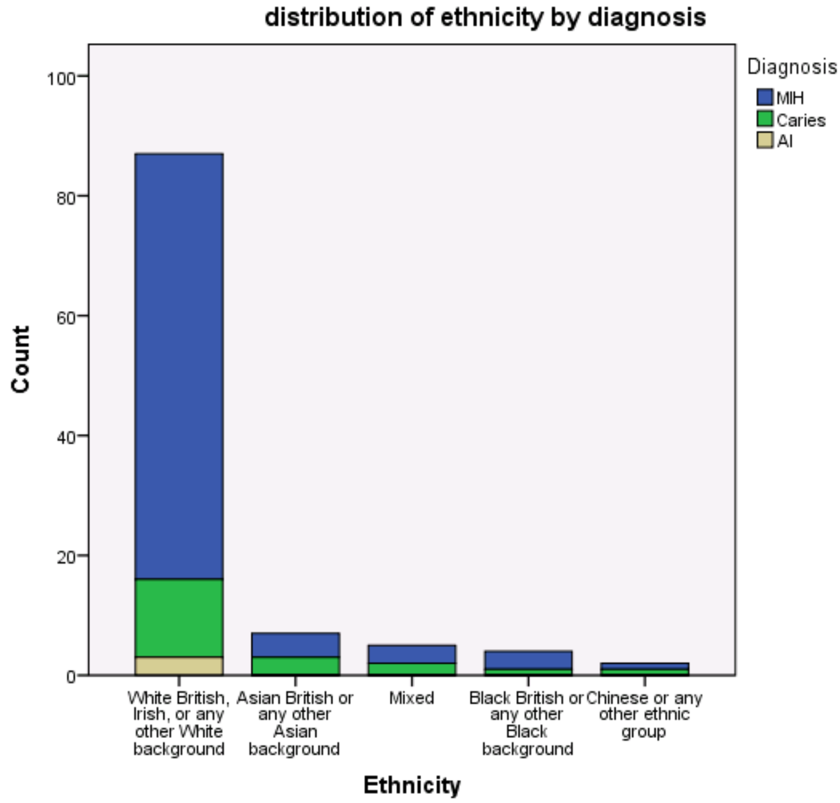


Figure 5-6: Distribution of ethnicity by diagnosis

5.4.4 Socioeconomic status

Socioeconomic status was determined using the patient's home postcode, in which a corresponding IMD quintile was produced. Quintile 1 (IMD score ≤ 8.49) represents the 20% least deprived and therefore higher socioeconomic status, and quintile 5 (IMD score ≥34.18) represents the 20% most deprived. Therefore, the higher the IMD quintile, the lower the socioeconomic status.

Half of the children in this study live in the two lowest socioeconomic quintiles: 30% (n=32) in quintile 5, and 21% (n=23) in quintile 4. Table 5-1 shows the distribution of the children in this study (n=105) within the range of quintiles.

Table 5-1: Distribution of children within the IMD quintiles

IMD quintile	Number of subjects (%)
1	12 (11.4%)
2	21 (20.0%)
3	17 (16.2%)
4	23 (21.9%)
5	32 (30.5%)
Total	105 (100%)

5.4.4.1 Socioeconomic status of MIH and Caries children

It was evident from Figure 5-7 that Caries subjects were in the lowest socioeconomic groups (Quintile 3, 4, and 5) whereas MIH subjects were distributed throughout the quintiles. A Mann-Whitney U test was run to determine if there were differences in IMD quintiles (socioeconomic status) between MIH and Caries groups. There was a statistically significant difference in distributions of IMD quintiles for MIH and Caries children, $U= 473$, $z= -3.0$, $p= .003$.

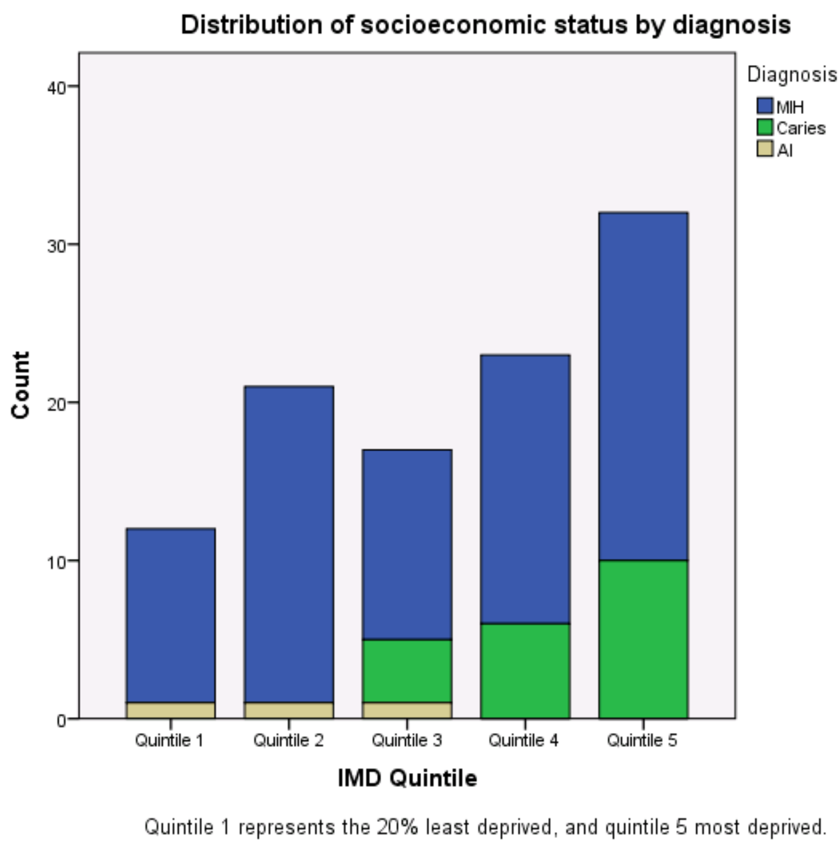


Figure 5-7: Distribution of socioeconomic status (IMD quintile) by diagnosis

5.5 Clinical records

5.5.1 Dental impressions and study models

A total of 99 children in this study had upper and lower alginate impressions successfully taken for orthodontic study models fabrication: 91 impressions were taken by the primary investigator [HB], 6 by the dental therapist [SH], and 2 by the examining clinicians, as they needed impressions for fabrication of an upper removable appliance and a sports guard.

5.5.2 OPT radiograph and dental age

5.5.2.1 OPT and absent permanent teeth

Dental age was assessed using the Demirjian method (Demirjian & Goldstein, 1976), which involved rating the stages of development of the 7 permanent teeth on the lower left side of an OPT radiograph. Two children had a developmentally missing lower left second premolar, and so the contralateral premolar on the right side was rated instead.

There were 5 children participants who had bilateral developmentally absent lower second premolars (PM_2) and 1 participant with absent bilateral lower lateral incisors (I_2). It would not be beneficial to exclude those patients from dental age assessment for that reason alone. For the purposes of this research, the score for the missing second premolar was therefore substituted with the values taken from the median tooth formation stage by age table published by Liversidge (2010) (Appendix 18).

5.5.2.2 OPT radiograph date

Most children had an OPT radiograph taken on the date of initial assessment (n=89), however, some children had previously existing radiographs (n=16). All OPT radiographs were assessed for dental age using the modified Demirjian system (1976), as previously described. For those children with previously existing radiographs, the dental age was adjusted by adding the difference of duration between the date OPT was taken and the date of initial consultation assessment (Table 5-2).

Table 5-2: Dental age adjustments for subjects with existing OPT radiographs

Subject number	Dental age from existing OPT (years)	Difference between date of OPT and date of initial consultation		Adjusted dental age (years)
		Days	Years	
#003	9.3	158	0.432	9.7
#006	7.7	266	0.728	8.4
#013	10.7	38	0.104	10.8
#017	10.0	135	0.369	10.3
#025	8.8	196	0.536	9.3
#029	7.3	140	0.383	7.6
#045	10.7	44	0.120	10.8
#048	6.1	500	1.369	7.4
#062	7.8	107	0.293	8.0
#067	9.0	48	0.131	9.1
#077	8.8	180	0.493	9.2
#087	8.5	465	1.273	9.7
#095	7.0	327	0.895	7.8
#097	7.8	402	1.101	8.9
#101	8.1	100	0.273	8.3
#115	8.6	603	1.652	9.0

5.6 Dental age

Dental age ranged from 6.7 to 13.0 years with a mean of 8.7 ±1.1 years. Dental age was normally distributed for both males and but not for females, as assessed by Shapiro-Wilk's test ($p < .05$).

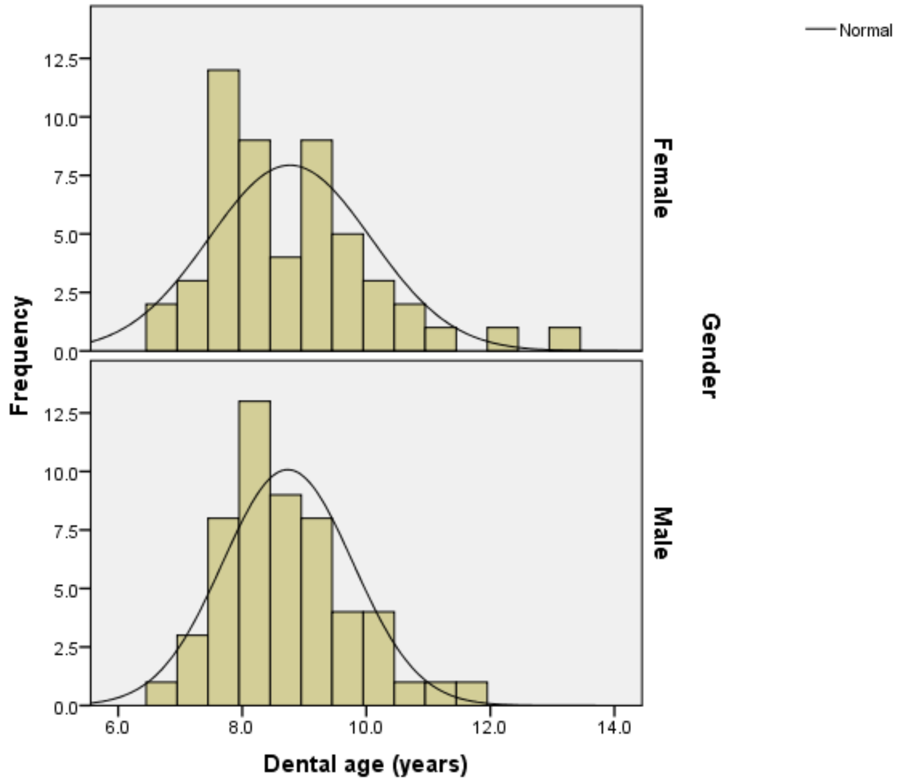


Figure 5-8: Distribution of dental age by gender

5.6.1 Relationship between dental age and chronological age

The scatterplot in Figure 5-9 displays that dental age and chronological age have a strong positive linear relationship, which was an expected finding.

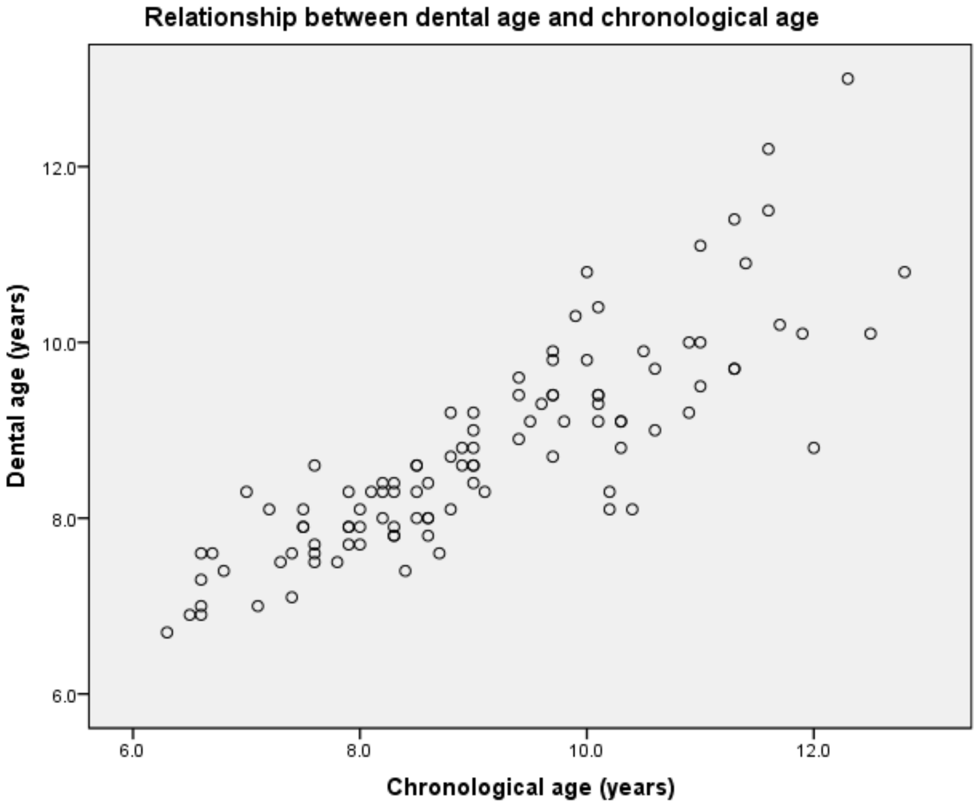


Figure 5-9: A scatterplot displaying strong positive linear relationship between chronological age an dental age

5.6.2 Lower SPM development stage

As part of dental age assessment, the lower SPM developing stage was rated for each child in this study. The UK national guidelines (2014, 2009) recommend an ‘ideal time’ for FPM extraction, when there is evidence of the beginning of radiographic calcification at the lower SPM root bifurcation (stage E) (Appendix 15).

Children in this study had lower SPM development in stages C, D, E, F, and G, as displayed in Figure 5-10. The majority (69.5%; n=73) had lower SPM in stages D or E. The relationship between lower SPM and agreed treatment plan was explored in later sections.

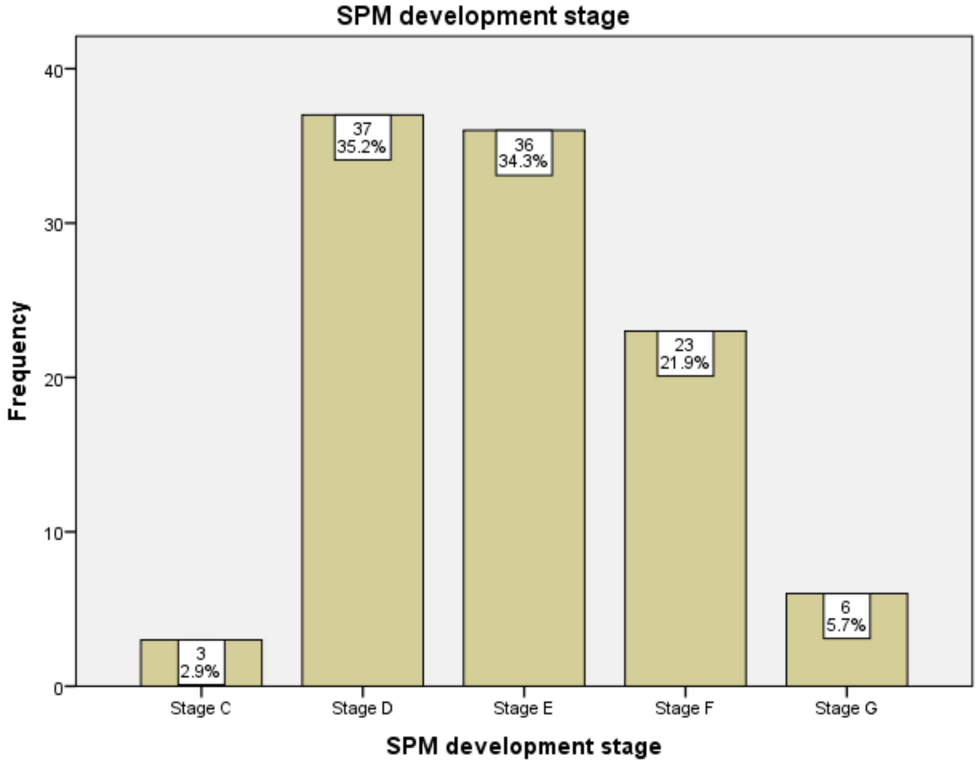


Figure 5-10: Distribution of children's lower SPM developing stage (n=105)

5.7 Dental anxiety

The MCDASf questionnaire was used to measure dental anxiety levels of the 105 children in this study. Total MCDASf score range from 8 to 40; and the cut-off level for 'anxious' is ≥ 26. The children in this study (n=105) had a mean anxiety score of 19.8 ± 6.6, which tells us that the children as whole do not have increased dental anxiety; although a fifth of children (20.0%; n=21) displayed dental anxiety (MCCDASf ≥ 26). Differences in dental anxiety for different ages, genders, and diagnosis has been explored in the below sections.

5.7.1 Anxiety and chronological age

The relationship between total MCDASf anxiety score and chronological age was explored, and there was no statistical significant relationship found, as assessed by a Pearson's product-moment correlation $p > .05$.

5.7.2 Anxiety and gender

Girls had higher mean anxiety levels (21.2 ± 6.5) than boys (18.6 ± 6.5). A point-biserial correlation was run between gender and anxiety score, which showed a statistically significant correlation between gender and anxiety score, rpb = .196, p= .045. The strength of the association was small, where gender accounted for 3.8% of the variability in anxiety scores.

Of the 21 children who were at the cut-off level for dentally ‘anxious’, 14 (26.9%) were females and 7 (13.2%) were males. This difference in proportions was not found to be statistically significant, as tested using Fisher’s exact test, p=.092.

5.7.3 Anxiety and diagnosis

Difference in dental anxiety levels between MIH (n=82), Caries(n=20), and AI(n=3) children was tested using one-way ANOVA. There were no outliers, as assessed by boxplot; data was normally distributed, as assessed by Shapiro-Wilk test (p > .05); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances (p = .191). Mean anxiety levels were slightly higher in MIH children (20.3 ± 6.5) than Caries children (18.4 ± 7.1) and AI children (18.0 ± 3), but the differences between these groups were not statistically significant, F(3, 27) = 1.116, p = .523.

Of the 21 children who were at the cut-off level for dentally ‘anxious’, 17 (20.7%) were MIH-group, 4 (20.0%) were Caries-group, and 0 (0.0%) were AI-group; and there were no statistically significant differences in proportions, Fisher’s exact test p=1.000.

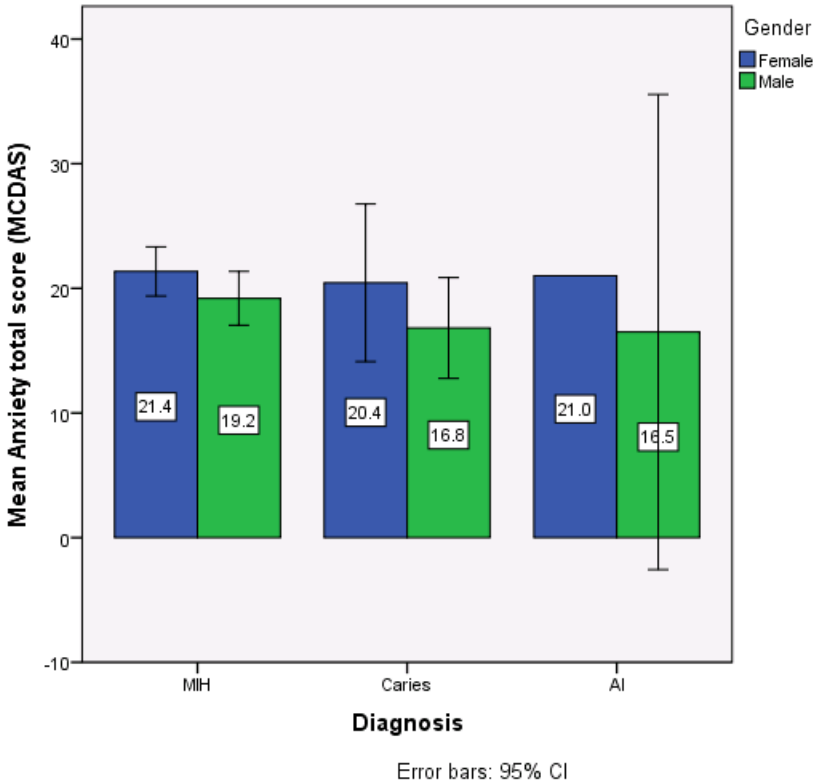


Figure 5-11: Mean dental anxiety scores by diagnosis and gender

5.7.4 Components of dental anxiety (MCDASf)

The MCDASf questionnaire consisted of 8 questions related to different aspects of a dental visit. The questionnaire (Appendix 11) had asked children to rate on a five-point scale with faces, whether they felt relaxed/not worried, verity slightly worried, fairly worried, worried a lot, or very worried.

The MCDASf scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.816; confirming its overall reliability for the set of 8 MCDASf questions. The range of anxiety levels for each of the 8 dental anxiety questions for the full study group (n=105) are shown in Figure 5-12.

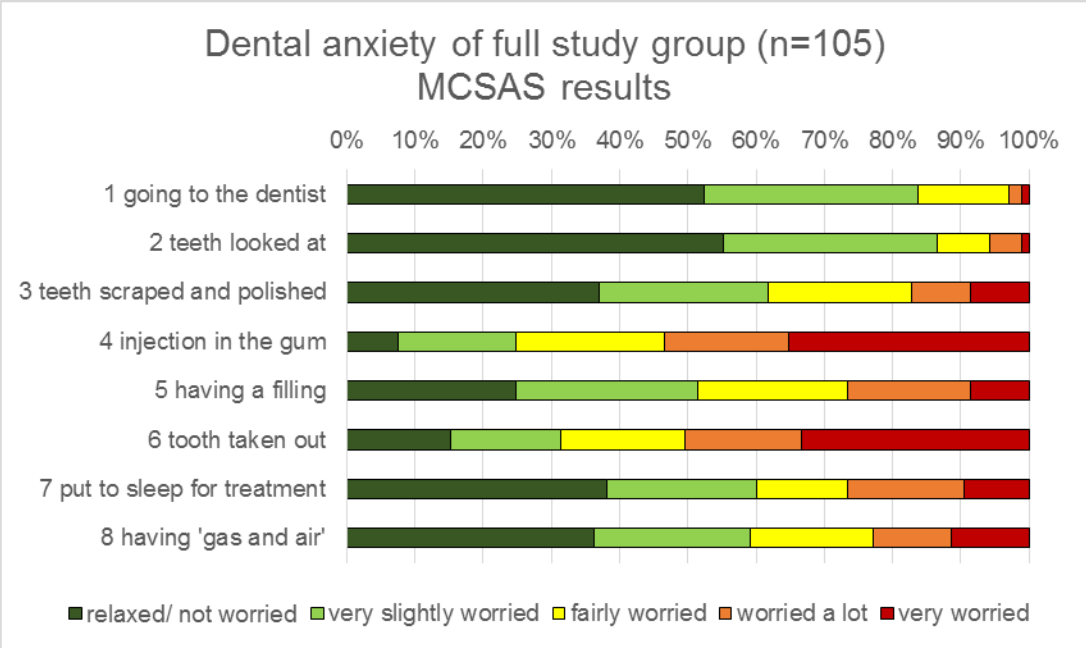


Figure 5-12: Ratings of components of dental anxiety

5.7.4.1 MCDASf components and differences by gender

Differences in each of the different MCDASf anxiety questions between female and male genders were explored using Mann-Whitney U tests. The mean scores for 3 out of the 8 MCDASf questions were statistically significantly higher in girls than boys:

- '*teeth looked at*': females (very slightly worried; mean rank= 59.3); males (relaxed/not worried; mean rank= 49.7), U = 1048, z = -2.361, p = .018.
- *'tooth taken out':* females (worried a lot; mean rank= 58.7) males (fairly worried; mean rank= 47.3),U = 1079, z = -1.972, p = .049.
- *'having gas and air'*: females (fairly worried; mean rank= 63.0); males (relaxed/not worried; mean rank= 43.1), U = 856, z = -3.462, p = .001.

There were no statistical significant differences in scores between males and females for '*going to the dentist'*, '*teeth scraped and polished'*, '*injection in the gum'*, '*having a filling'*, and '*put to sleep for treatment'*.

5.7.4.2 MCDASf components and differences between MIH and Caries

Mann-Whitney U tests were run to determine if there were differences in each of the 8 different MCDASf anxiety questions between children with diagnosis of MIH and Caries. Distributions of the scores of each of the MCDASf questions for MIH and Caries groups were similar, as assessed by visual inspection of boxplots.

The score for '*having a filling'* was higher in MIH (fairly worried; mean rank= 54.6) than Caries (very slightly worried; mean rank =38.8) children, which was statistically significantly different, U = 566, z = -2.194, p = .028.

Scores for MIH and Caries children were not statistically significantly different for '*going to the dentist'*, '*teeth looked at'*, '*teeth scraped and polished'*, '*injection in the gum*', ' *tooth taken out'*, '*put to sleep for treatment'*, and '*having gas and air'*.

5.8 Oral health related QoL

The COHIP-SF19 questionnaire was used to measure oral health related QoL levels of the 105 children in this study, and consisted of 19 questions. The questionnaire (Appendix 12) had asked children to rate on a five-point scale whether they experienced the item in question almost all the time, fairly often, sometimes, almost never, or never. The COHIP-SF19 scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.871.

5.8.1 QoL and chronological age

A Pearson's product-moment correlation was run to assess the relationship between QoL score and chronological age and there was no statistical significant relationship found, $p > 0.05$.

5.8.2 QoL and gender

Mean QoL scores for girls (23.7 ± 12) and boys (22.1 ± 12.9) were similar, and there was no statistically significant correlation between gender and QoL scores. Gender did not account for any variability in QoL scores.

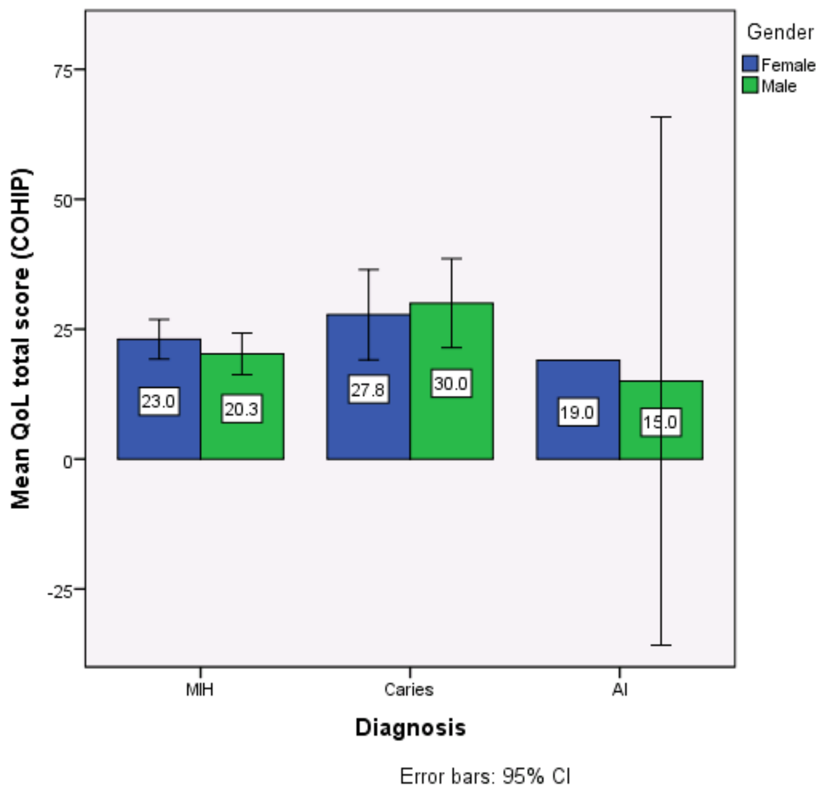


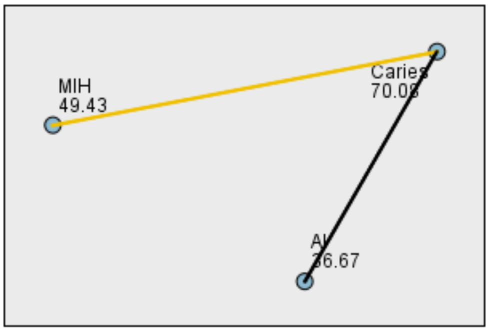
Figure 5-13: Mean oral health related QoL scores by diagnosis and gender

5.8.3 QoL and diagnosis

Mean QoL scores were higher in Caries children (29.0 ± 11.8) than MIH children (21.6 ±12), and lowest in AI children (16.3 ± 4.6).

A Kruskal-Wallis H test was conducted to determine if there were significant differences in total QoL scores between the MIH, Caries, and AI diagnosis groups. Distributions of QoL scores were not similar for all groups, as assessed by visual inspection of a boxplot. QoL scores were statistically significantly different between the different diagnosis groups, $\chi2(2) = 8.287$, $p = .016$. Subsequently, pairwise comparisons were performed using Dunn's procedure. A Bonferroni correction for multiple comparisons was made with statistical significance accepted at the $p < .05$ level. This post hoc analysis revealed statistically significant differences in QoL scores between MIH (mean rank = 49.4) and Caries (mean rank = 70.0) ($p = .020$) groups, but not between AI group (mean rank = 36.6) or any other group combination.

Pairwise Comparisons of Diagnosis



Each node shows the sample average rank of Diagnosis.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
AI-MIH	12.766	17.888	.714	.475	1.000
AI-Caries	33.408	18.842	1.773	.076	.229
MIH-Caries	-20.642	7.589	-2.720	.007	.020

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 5-14: Pairwise comparisons of oral health related QoL by diagnosis

5.8.4 QoL components (COHIP-SF19)

The range of anxiety levels for each of the 19 QoL questions as part of the oral health wellbeing, functional wellbeing, and social-emotional wellbeing subscales for the full study group (n=105) are shown in Figure 5-15.

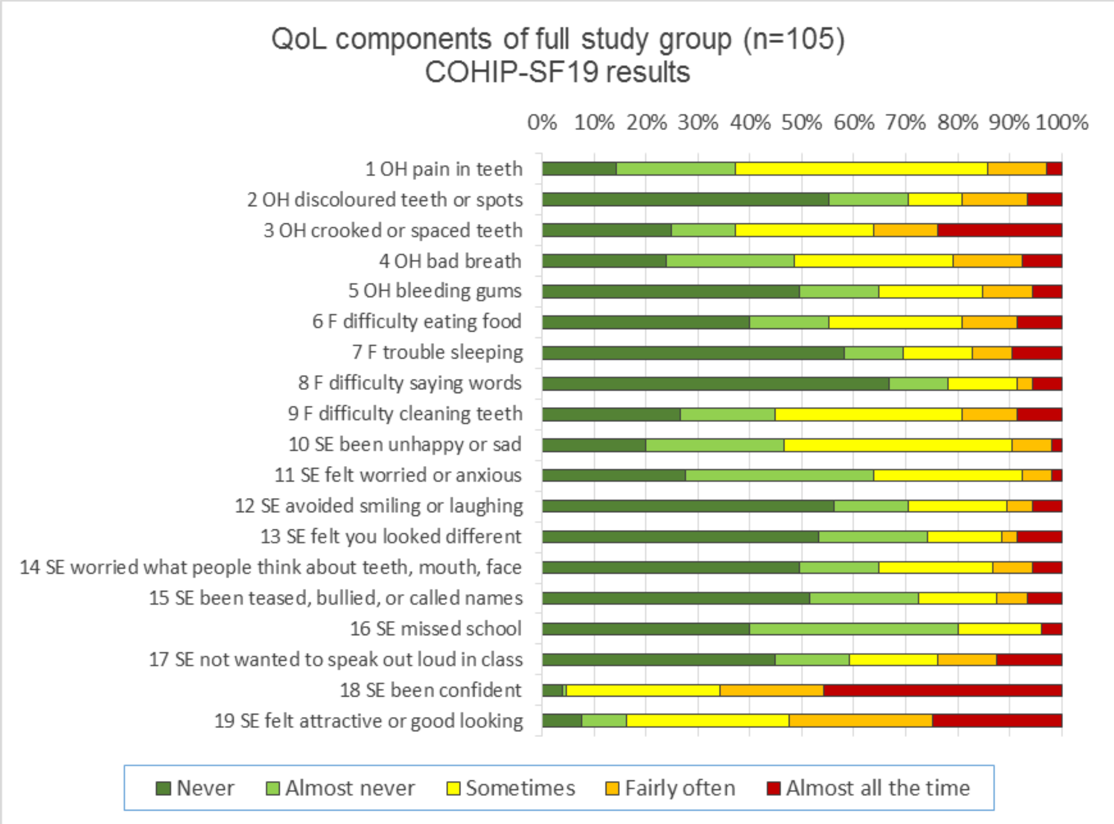


Figure 5-15: Ratings of components of oral-health-related QoL

5.8.4.1 QoL components and differences in gender

Mann-Whitney U tests were run to determine if there were differences in each of the COHIP-SF19 questions under the oral health wellbeing, functional wellbeing, and social-emotional wellbeing between female and male genders. The distributions of the scores for males and females were similar and no statistically significant differences were found between the genders, $p>.05$.

5.8.4.2 QoL components and differences between MIH and Caries

Mann-Whitney U tests were run to determine if there were differences in each of the different COHIP-SF19 QoL questions between children with diagnosis of MIH and Caries. 4 out of the 19 COHIP questions showed differences between MIH and Caries group:

Oral health wellbeing: There were no significant differences between scores of the MIH and caries groups in all of the five components of the oral health wellbeing subscale: ‘pain in teeth’, ‘discoloured teeth or spots’, ‘crooked or spaced teeth’, ‘bad breath’, ‘bleeding gums’.

Functional wellbeing (F): Caries group showed statistically significantly higher scores than MIH group in two out of the four components of the functional wellbeing subscale:

- ‘F- trouble sleeping’ - Caries (sometimes; mean rank= 67.3); MIH (never; mean rank= 47.6), U = 504, z = -2.958, p = .003.
- ‘F- difficulty cleaning teeth’ - Caries (sometimes ; mean rank= 64.4); MIH (almost never ; mean rank= 48.3), U = 561, z = -2.269, p = .023

There were no differences between the groups in the remaining two components of that subscale: ‘difficulty eating food’ and ‘difficulty saying words’.

Social-emotional wellbeing (SE): there were statistically significant differences in scores of two out of the 10 components of the social-emotional subscale:

- ‘SE- not wanted to speak out loud in class’ - Caries (sometimes; mean rank=63.9); MIH (Almost never ; mean rank=48.4), U = 571, z = -2.205, p = .027
- ‘SE- been confident’ - MIH (almost all the time; mean rank= 63.7); Caries (sometimes; mean rank= 48.5), U = 574, z = -2.219, p = .026

There were no differences between the groups in the remaining eight components of this subscale: ‘been unhappy or sad’, ‘felt worried or anxious’, ‘avoided smiling or laughing’, ‘felt you looked different’, ‘worried about what people think about teeth, mouth, or face’, ‘missed school’, ‘felt attractive or good looking’.

5.9 Clinical features- Enamel defects and disease severity

5.9.1 Enamel defects

FPM and permanent incisors of all children in this study were assessed for presence of enamel defects, using intraoral clinical photographs of various views (Appendix 13), by the primary investigator [HB], after being calibrated with the mDDE index (1989) from the photograph slides produced by Balmer (2012).

5.9.1.1 FPM enamel defects by subject

Children in this study had each of their FPM assessed for presence of enamel defects, which were categorised into DO, PEB, AT restoration/cavity, diffuse, hypoplastic and combination defects. Absence of FPM enamel defect, previously extracted FPM, and unerupted FPM were also documented.

All children with PEB, DO, and AT defects on their FPM were in the MIH group. In the Caries group, all children had no enamel defect on FPM, of which one also had a previously extracted FPM. Hypoplastic, diffuse and combination defects on FPM were only present in AI children. The distribution of FPM defects by child's diagnosis is shown in Table 5-3.

Table 5-3: Distribution of FPM defects by subject in MIH, Caries, and AI groups

FPM defect type (on at least 1 FPM by subject)	Diagnosis			Total subjects
	MIH	*Caries*	*AI*	
PEB	70 (85.3%)	0 (0%)	0 (0%)	70 (66.6%)
DO	53 (65.6%)	0 (0%)	0 (0%)	53 (50.4%)
AT	16 (19.5%)	0 (0%)	0 (0%)	16 (15.7)
Diffuse	0 (0%)	0 (0%)	1 (33.3%)	1 (0.9%)
Hypoplastic	0 (0%)	0 (0%)	1 (33.3%)	1 (0.9%)
Combination defects	0 (0%)	0 (0%)	1 (33.3%)	1 (0.9%)
No enamel defect	45 (54.8%)	20 (100%)	0 (0%)	65 (61.9%)
Previously extracted FPM	0 (0%)	1 (5.0%)	0 (0%)	1 (0.9%)
Unerupted FPM	2 (2.4%)	0 (0%)	0 (0%)	2 (1.9%)
Total subjects	82 (100%)	20 (100%)	3 (100%)	105 (100%)

Note: This table displays number of subjects having at least 1 FPM with that defect and, with percentage per column in parentheses.
Key: FPM = First permanent molar; PEB= Posteruptive enamel breakdown; DO= Demarcated opacity; AT= Atypical restoration/cavity pattern.

5.9.1.2 FPM enamel defects by FPM teeth

MIH group: The 82 children in the MIH group collectively had a total of 326 erupted FPM, of which 256 (78.5%) had a type of enamel defect present. More than half of the FPM enamel defects were PEB (n= 149; 58.2%), about a third were DO (n= 83; 32.4%), and only 9.3% (n= 24) were AT restoration or cavity pattern. There was no significant difference in the location of FPM affected with enamel defect: UR6 (n=67); UL6 (n=67); LL6 (n=59); LR6 (n=57), p >0.05.

Table 5-4: Distribution of FPM enamel defect by tooth in MIH group

FPM defect type	FPM teeth in MIH group				Total FPM (%)
	UR6	*UL6*	*LL6*	*LR6*	
PEB	39	34	36	40	149 (45%)
DO	23	25	18	17	83 (25%)
AT	5	8	5	6	24 (7%)
Diffuse	0	0	0	0	0 (0%)
Hypoplastic	0	0	0	0	0 (0%)
Combination defects	0	0	0	0	0 (0%)
No enamel defect	13	15	23	19	70 (21%)
Previously extracted FPM	0	0	0	0	0 (0%)
Unerupted FPM	2	0	0	0	2 (0.6%)
Total FPM	82	82	82	82	328 (100%)

Note: This table displays number of FPM teeth for MIH group only.
Key: FPM = First permanent molar; PEB= Posteruptive enamel breakdown; DO= Demarcated opacity; AT= Atypical restoration/cavity pattern.

Caries group: All 20 children in the Caries group did not show any evidence of enamel defect in their FPM (n= 79 FPM). One of these children had a previously extracted FPM (n=1 FPM).

AI group: Of the 3 children in the AI group, 1 had diffuse defects (n=4 FPM), 1 had hypoplastic defects (n=4 FPM) and 1 had hypoplastic/diffuse combination defect (n=4 FPM).

5.9.1.3 Incisors enamel defects by subject (child-level)

Children in this study had each of their 8 permanent incisors assessed for presence or absence of enamel defects. The prevalence of presence of any type of enamel defects on permanent incisors in the full study group (n=105) was 70.4% (n=74). This prevalence however, was not representative of the general population, as there were unequal numbers of children in MIH, Caries, and AI groups. There was an incisor enamel defect prevalence on a child-level of 81.7% (n=67) in the MIH group, and 20% (n=4) in the Caries group. 100% of the AI children (n=3) had enamel defects on their incisors, which was expected due to the nature of the disease.

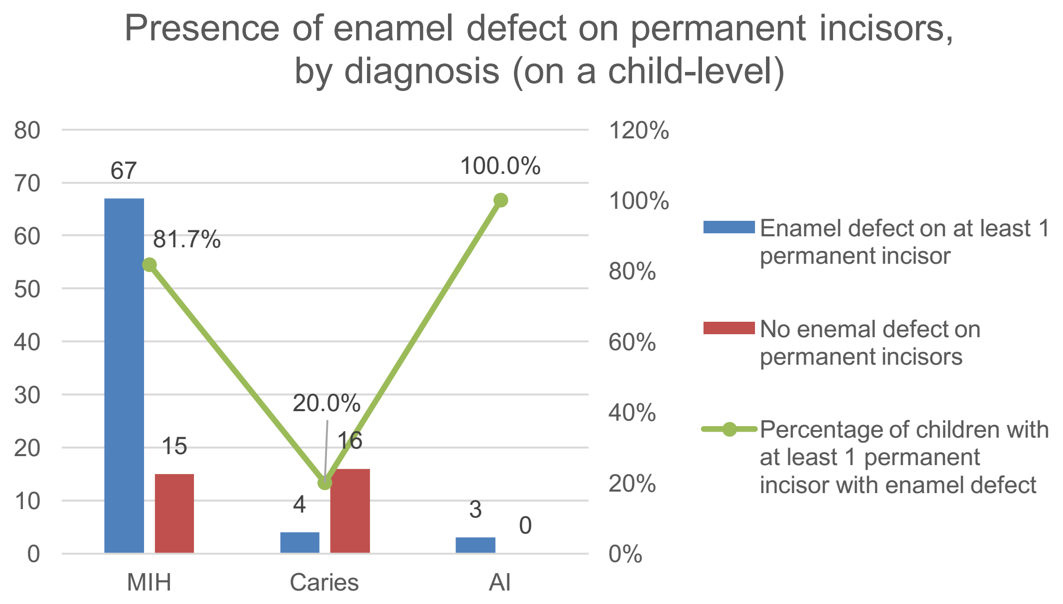


Figure 5-16: Presence of enamel defect on permanent incisors by subject (n=105)

Children's incisor enamel defects were categorised into DO-white/cream, DO-yellow/brown, diffuse, hypoplastic, and combination defects. Permanent incisors which were not yet erupted, or developmentally absent were noted.

All children with DO on permanent incisors, whether white/cream (75.6%; n=62) or yellow/brown (19.5%; n=16), were in the MIH group (78.0%; n=64). Diffuse enamel defects on at least 1 permanent incisor were present in children with MIH (3.6%; n=3), Caries (15.0%; n= 3) and AI (100%; n=3). Hypoplastic defect was only present in a child with Caries (5.0%; n=1). Table 5-5 shows the types of incisor enamel defects in children in his study.

Table 5-5: Incisor enamel defect types by diagnosis (number of subjects)

Incisor defect type	Diagnosis			Total subjects
	MIH	*Caries*	*AI*	
DO (white/cream)	62 (75.6%)	0 (0%)	0 (0%)	62 (59.0%)
DO (yellow/brown)	16 (19.5%)	0 (0%)	0 (0%)	16 (15.2%)
Diffuse	3 (3.6%)	3 (15.0%)	3 (100%)	9 (8.5%)
Hypoplastic	0 (0%)	1 (5.0%)	0 (0%)	1 (0.9%)
Combination defects	0 (0%)	0 (0%)	0 (0%)	0 (0%)
No enamel defect	81 (98.7%)	20 (100%)	0 (0%)	101 (96.1%)
Developmentally absent incisor	6 (7.3%)	2 (10.0%)	0 (0%)	8 (7.6%)
Unerupted incisor	25 (30.4%)	2 (10.0%)	0 (0%)	27 (25.7%)
Total subjects	82 (100%)	20 (100%)	3 (100%)	105 (100%)

Note: This table displays number of subjects having at least 1 incisor with that defect and, with percentage per column in parentheses.
Key: FPM = First permanent molar; PEB= Posteruptive enamel breakdown; DO= Demarcated opacity; AT= Atypical restoration/cavity pattern.

5.9.1.4 Incisors enamel defects by teeth (tooth-level)

MIH group: Children in the MIH group had a total of 588 incisors present, as 58 incisors were unerupted and 10 incisors were developmentally absent. Prevalence of incisor enamel defect in MIH children at tooth level was 25.1% ($\frac{148}{588}$). Distributions of and type of enamel defects by tooth number is shown in Table 5-6, and presence of enamel defect by tooth type in Figure 5-17.

Of the 148 incisors with enamel defects, DO- white/cream was the most common (81.0%; n=120 incisors), followed by DO- yellow/brown (15.5%; n=23 incisors), and diffuse defect with only 3.3% (n=5 incisors).

With regards to the location of the affected incisors, 55.4% (n=82 incisors) were upper centrals, 20.2% (n=30 incisors) were lower laterals, 17.5% (n=26 incisors) were lower centrals, and only 6.7% (n=10 incisors) were upper laterals.

Table 5-6: Distribution of incisor enamel defect types by tooth in MIH children

FPM defect type	Incisor tooth (MIH group)								Total Incisors
	UR2	*UR1*	*UL1*	*UL2*	*LL2*	*LL1*	*LR1*	*LR2*	
DO (white/cream)	4	34	32	4	7	11	12	16	120
DO (yellow/brown)	0	4	7	2	3	1	2	4	23
Diffuse	0	3	2	0	0	0	0	0	5
Hypoplastic	0	0	0	0	0	0	0	0	0
Combination defects	0	0	0	0	0	0	0	0	0
No enamel defect	50	38	38	55	66	70	68	55	440
Developmentally absent incisor	4	0	0	5	1	0	0	0	10
Unerupted incisor	24	3	3	16	5	0	0	7	58
Total	82	82	82	82	82	82	82	82	656

Note: This table displays number of incisor teeth in MIH group.
Key: FPM = First permanent molar; PEB= Posteruptive enamel breakdown; DO= Demarcated opacity; AT= Atypical restoration/cavity pattern.

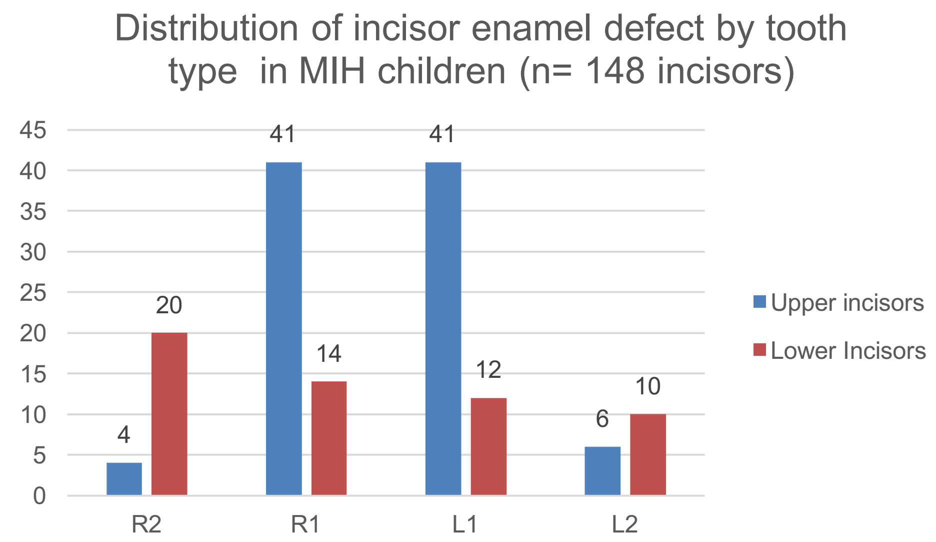


Figure 5-17: Number and distribution of incisors with enamel defect in MIH children

Caries group: Children in the caries group had a total of 152 incisors present, 4 incisors were unerupted, and 4 were developmentally absent. The prevalence of incisor enamel defect at tooth level in Caries children was 3.9% ($\frac{6}{152}$). Diffuse defects were present in 5 incisors (4 upper centrals, and 1 lower lateral), and only 1 incisor exhibited a hypoplastic defect (an upper lateral incisor).

AI group: All 3 children in the AI group had diffuse enamel defects of all their incisors (n=24 incisors).

5.9.2 FPM severity – MIH group (n=82)

Clinical photographs were used to assess severity of MIH as described previously into *mild* (demarcated opacities with no structural loss of tooth tissue), *moderate* (enamel opacities associated to PEB limited to enamel), and *severe* (associated with structural loss of tooth tissue into dentine).

5.9.2.1 MIH severity per FPM (tooth-level)

Each of the 326 FPM present in MIH children were assessed for defect severity, and 22% (n=70) had no enamel defects; while 43% (n=140) were severe, 25% (n=83) were mild, and only 10% (n=33) were moderate. The distribution of enamel defect severity by FPM tooth number is present in Figure 5-18.

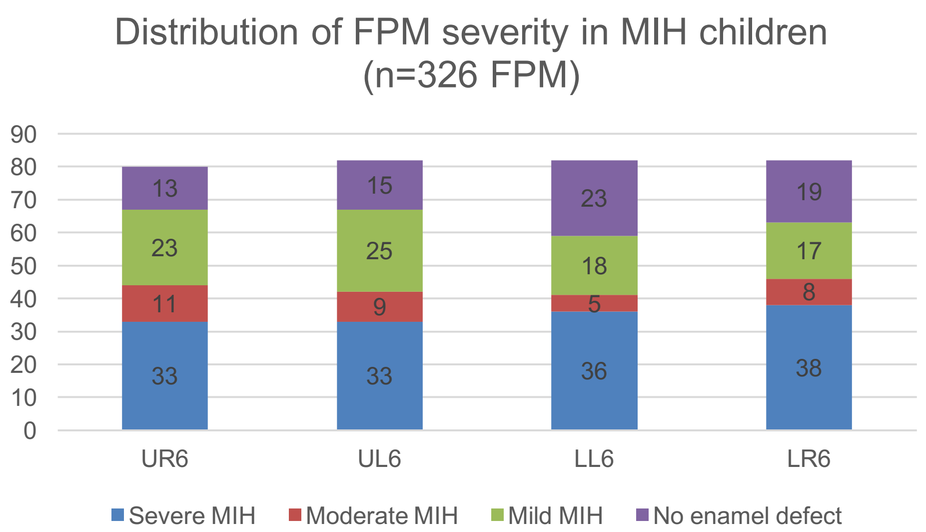


Figure 5-18: Distribution of FPM severity by tooth in MIH children

5.9.2.2 MIH severity per child (child-level)

Children with MIH were given an overall MIH severity rating, which corresponds with the most severe FPM rating. Of the 82 children in the MIH group, 72 (87.8%) had 1 or more FPM with severe MIH. There were equivalent numbers of children with an overall MIH rating of moderate (n=5; 6.5%) and mild (n=5; 6.1%).

5.9.3 FPM severity – Caries group (n=20)

Clinical photographs were used to assess severity of Caries group, as described previously into *mild* (1 surface caries on FPM), *moderate* (2 or more surfaces of FPM), and *severe* (FPM caries into pulp or retained roots).

5.9.3.1 FPM caries severity per FPM (tooth-level)

Each of the 79 FPM present in Caries group children were assessed for FPM caries severity, and 27.8% (n=22) were sound; while 39.2% (n=32) were mild, 26.5% (n=21) were severe, and only 6.3% (n=5) were moderate.

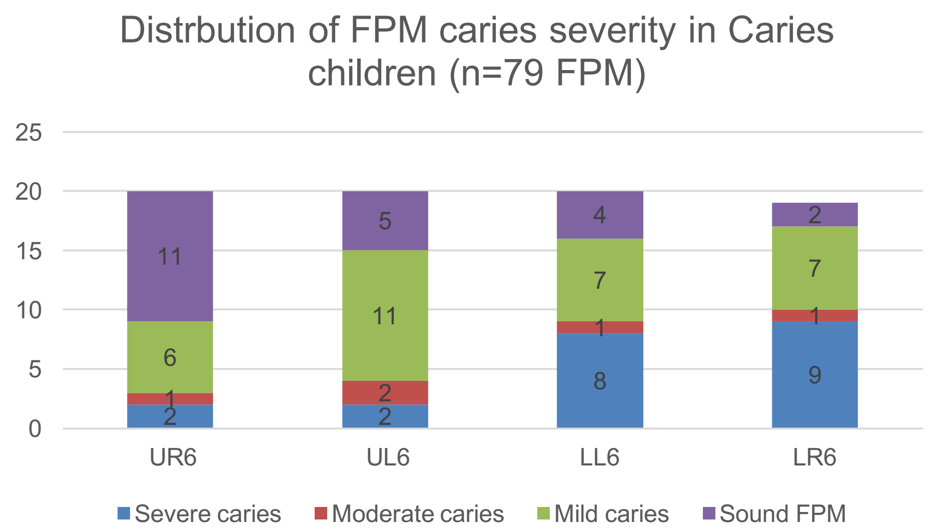


Figure 5-19: Distribution of FPM caries severity by tooth in Caries children

5.9.3.2 FPM caries severity per child (child-level)

Children in the Caries group were given an overall severity, which corresponds to the most severely carious FPM. Out of the 20 children in the Caries group, 13 (65.0%) had severe caries on one or more FPM, 6 (30.0%) had mild, and only 1 (5.0%) had moderate FPM caries.

5.9.4 FPM severity – AI group (n=3)

FPM severity in AI children was assessed as mild (no enamel loss) and severe (enamel loss). There were 2 children with mild AI (n=8 FPM), and 1 child with severe AI (n=4 FPM).

5.9.5 Disease severity by number of FPM affected

Number of FPM teeth affected in children with MIH (n=82), Caries (n=20), and AI (n=3) was used as an overall way to assess MIH, Caries, and AI disease severity. The mean number of affected FPM was highest in AI children (4.0 ± .0), followed by MIH children (3.1 ± .92), and very slightly lower in Caries children (2.9 ± .85). Although the minimum affected FPM was 1 in MIH, 2 in Caries, and 4 in AI children, there was no statistically significant differences in number of affected FPM between the diagnoses, Kruskal-Wallis H test $\chi2(2) = 4.705$, $p = .095$.

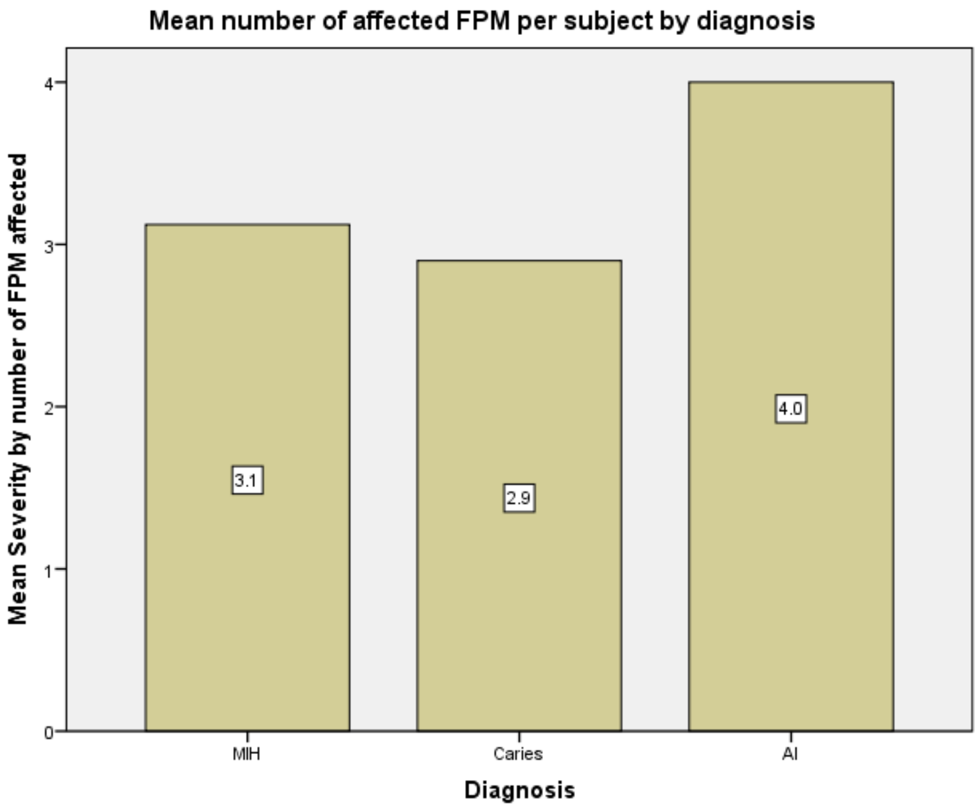


Figure 5-20: Mean number of affected FPM per child in MIH, Caries, and AI groups

5.9.5.1 Number of affected incisors and diagnosis

A Kruskal-Wallis H test was run to determine if there were differences in number of incisors with enamel defect within children of MIH, Caries, and AI diagnoses. Distributions were not similar for all groups, as assessed by visual inspection of a boxplot.

Mean number of incisors with enamel defect was highest in AI children (8 ± 0.0), followed by MIH (1.79 ± 1.4), and lowest in Caries children (0.67 ± 0.1). The number of affected incisors were significantly different between groups, $\chi2(2)$ = 30.435, $p < .0005$.

5.9.5.2 Number of affected incisors and FPM in MIH children

In MIH children (n=82), an increase in the number of hypomineralised FPM was statistically significantly associated with an increase in number of incisors with enamel defects; as per Spearman's rank-order correlation, rs= .302, p = .006.

5.10 Hypomineralised primary molars (HPM) in MIH children

The clinical photographs were assessed for presence of HPM by the primary investigator [HB], which was repeated after at least 3-4 weeks for intra-examiner agreement. Using the EAPD MIH criteria, presence of HPM was recorded if there was any opacities altering the translucency of enamel, posteruptive enamel breakdown, or atypical cavity patterns/restorations in the primary molars (Weerheijm et al., 2003).

5.10.1 HPM- patient level

Out of the 82 children in the MIH group, 26 (31.7%) had one or more hypomineralised primary molars. The remaining 49 (59.8%) had no primary molar defects, and 7 (8.5%) had no primary molars present. Examples of HPM in this study are presented in Figure 5-21 and Figure 5-22.

Figure 5-21: A 6.6 year old boy with MIH (#044) displaying atypical caries pattern on upper E's involving palatal cusps and LLE involving lingual surface, indicative of primary molar hypomineralisation.

Figure 5-22: 8.6 yr old girl with MIH (#061) and hypomineralsed primary molars mildly affecting ULE, URE, LLE with white and yellow opacities and no enamel loss.

5.10.1.1 Association between MIH severity and presence of HPM

Out of the 82 children, 72 (87.8%) had severe MIH, 5 (6.0%) had moderate, and 5 (6.0%) had severe MIH. The association between MIH severity and presence of HPM was explored using Fisher's exact test and there were some statistically significant differences in proportions.

In statistics, expected frequency (or expected count) is a probability count that appears in contingency table calculations (such as Fisher's exact test and Chi-square test). Adjusted residuals are the difference between observed and expected counts divided by the standard error; residuals below -2 or above +2 show that it is markedly different from the expected value (Lund & Lund, 2013).

As clearly seen in Table 5-7, 80% (n=4) of children with Mild MIH had HPM, which was triple the expected frequency (adjusted residual +2.9). Children with severe MIH, however had significantly more cases with no HPM (adjusted residual +4.8). Both these findings were statistically significant, as per Fisher's exact test, p< .0005. There was no statistically significant difference in Moderate MIH and presence of HPM.

Table 5-7: Cross-tabulation of MIH severity and presence of HPM

HPM in MIH children		MIH severity		
		Mild	*Moderate*	*Severe*
No HPM	*Count (%)*	1 (20.0%)	3 (20.0%)	45 (62.5%)
	Expected count	2.3	2.3	33.6
	Adjusted residual	(-1.2)	(-1.2)	**(4.8)**
HPM on at least 1 primary molar	*Count (%)*	4 (80.0%)	1 (20.0%)	21 (29.2%)
	Expected count	1.2	1.2	17.8
	Adjusted residual	**(2.9)**	(-0.3)	(1.5)
No primary molars present	*Count (%)*	0 (0%)	1 (20.0%)	6 (8.3%)
	Expected count	0.3	0.3	4.8
	Adjusted residual	(-0.6)	(1.2)	(1.0)
Total	*Count (%)*	5 (100%)	5 (100%)	72 (100%)
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages				

5.10.1.2 Severity of HPM by number of primary molars affected

Severity of HPM by number of primary molars affected per child is displayed in Figure 5-23, and ranged from 1 to 4 primary molars. The majority of children with HPM had 1 primary molar affected (n=11; 42.3%).

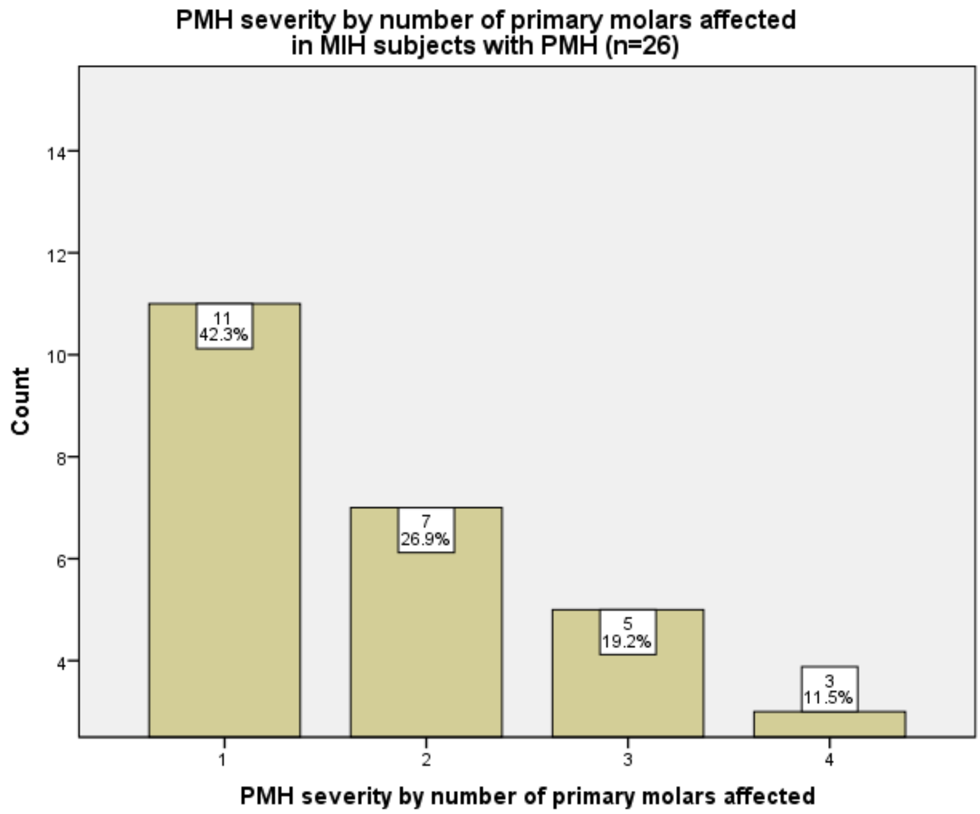


Figure 5-23: Severity by number of primary molars affected per child with MIH and HPM (n=26)

5.10.1.3 Association between number of primary molars affected and number of FPM affected in MIH children

There was no correlation between number of affected FPM and number of hypomineralised primary molars in MIH children, as tested by a Spearman's rank-order, rs = .037, p = .752.

5.10.2 HPM- tooth level

There was a total of 52 primary molars affected with HPM, and they were predominantly E's (second primary molars) (n=50; 96.1%). Only 2 D's (first primary molars) (3.8%) were affected. The distribution of HPM is shown in Figure 5-24.

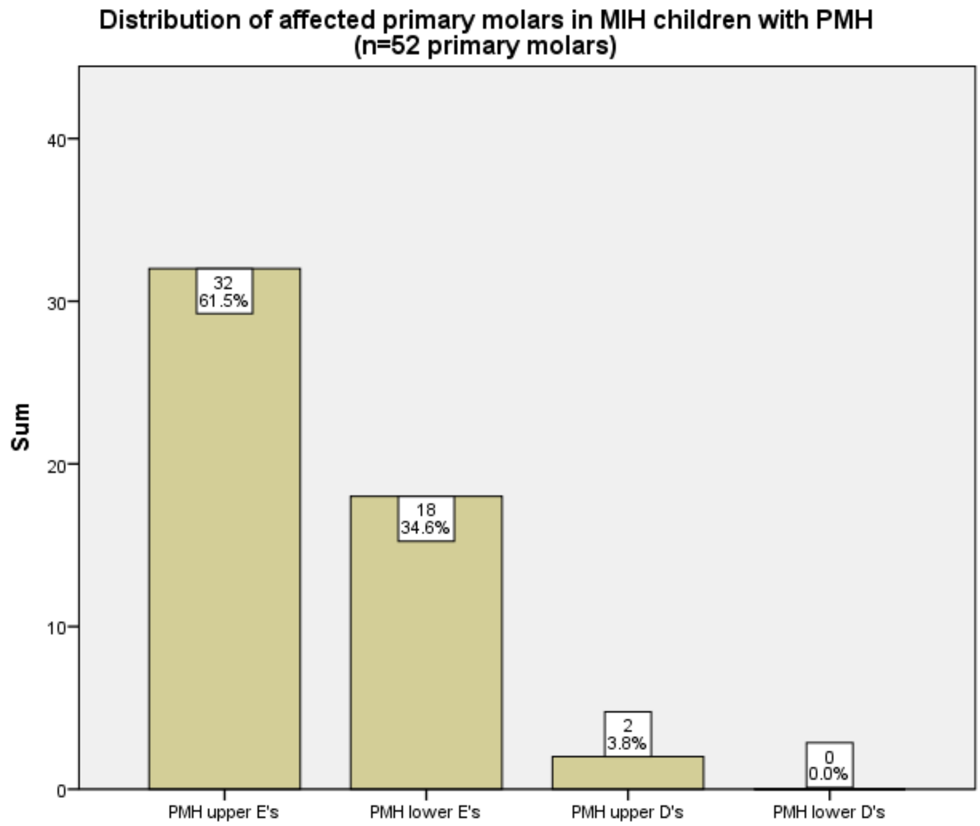


Figure 5-24: Distribution of affected primary molars in MIH children with HPM

5.11 Dental caries experience (DMFT/dmft)

All children in this study had their DMFT (permanent teeth) and dmft (primary teeth) assessed according to the WHO (2013). DMFT/dmft severity ranges from caries free (0), low (1-2), moderate (3-4) to high (≥ 5) (WHO, 2013). Table 5-8 shows caries distribution for permanent and primary teeth.

Table 5-8: Distribution of DMFT/dmft for full study group (n=105)

DMFT/ dmft	**Permanent dentition** Number of children (%)		**Primary dentition** Number of children (%)	
0	11	(10.4)	37	(37.7)
1	24	(22.8)	7	(7.1)
2	26	(24.7)	9	(9.1)
3	22	(20.9)	8	(8.1)
4	18	(17.1)	7	(7.1)
5	0	(0.0)	8	(8.1)
6	0	(0.0)	7	(7.1)
7	2	(1.9)	4	(4.0)
8	1	(0.9)	7	(7.1)
9	0	(0.0)	2	(2.0)
10	0	(0.0)	1	(1.0)
11	1	(0.9)	0	(0.0)
12	0	(0.0)	1	(1.0)
Total children	**105**	**(100)**	**98**	**(100)**

5.11.1 Permanent teeth – DMFT

Caries prevalence: Out if the 105 children in this study, 11 (10.4%) had no caries in the permanent dentition. Caries prevalence was 89.5% for the full study group. MIH, Caries, and AI children had a caries prevalence of 90.2%, 100.0%, and 0.0%, respectively.

Mean DMFT: A total of 245 decayed, missing, filled permanent teeth were present in the full study group (n=105); therefore, the mean DMFT was 2.33 ±1.78.

Mean DMFT for Caries children (3.45 ±1.73) (95% CI: 4.03, 2.67) was higher than in MIH children (2.17 ±1.67) (95% CI: 2.41, 1.69). None of the 3 AI children had a positive DMFT.

5.11.1.1 Difference in DMFT between MIH and Caries groups

Mann-Whitney U test was run to determine if there were differences in DMFT score between MIH and Caries children. Mean DMFT for Caries children (3.45 ±1.73) was statistically significantly higher than in MIH children (2.17 ±1.67), U = 457, z = -3.129, p = .002.

- *Decayed permanent teeth*: Caries children had statistically significantly higher mean decayed teeth due to caries (3.35 ±1.46) than MIH children (2.05± 1.63), U=387, z = -3.74, p < .0005.
- *Missing permanent teeth*: Although only 1 child had a missing permanent tooth, of which was in the caries group, a statistically significant difference was found, U= 779, z = -2.025, p = .043.
- *Filled permanent teeth*: MIH children had higher numbers of filled teeth (n=10; mean 0.12) compared to Caries children (n=1; mean 0.05); however, their means were similar and there was no statistically significant difference, U = 770, z = -.810, p = .418.

Table 5-9: Comparison of DMFT/dmft between MIH and Caries groups

	DMFT/ dmft Mean (± SD)	*U statistic (z)**	*P value**
Permanent teeth:			
MIH	2.17 (±1.67)	457 (-3.129)	.002
Caries	3.45 (±1.73)		
Primary teeth:			
MIH	2.44 (±2.79)	329 (-3.341)	.001
Caries	5.60 (±3.46)		

** Mann-Whitney U test*

5.11.1.2 DMFT and gender

Mean DMFT for males (2.39 ±1.81) was almost equal to females (2.31 ± 1.81). There was no statistically significant difference between the two genders for mean DMFT, U= 1337, z = -.268, p = .788.

Table 5-10: Comparison of DMFT/dmft between males and females

	DMFT/ dmft Mean (± SD)	*U statistic (z)**	*P value **
Permanent teeth:			
Male	2.36 (±1.81)	1337 (-.268)	.788
Female	2.31 (±1.81)		
Primary teeth:			
Male	3.04 (±3.21)	1166 (-.234)	.815
Female	2.72 (±2.92)		

** Mann-Whitney U test*

5.11.2 Primary teeth – dmft

There were 7 children (4 MIH, 3 Caries) with no primary teeth present, and therefore it was not possible to assess their dmft. The population in which prevalence was calculated was therefore 98 children (78 MIH, 17 Caries, and 3 AI)

Caries prevalence: Of the 98 children with primary teeth present, 37 (37.7%) had no caries in the primary dentition, of which 35 from MIH group, 1 Caries group, and 1 in AI group. Primary teeth caries prevalence was 62.2% (n= 61) for the full study group. MIH, Caries, and AI children had primary caries prevalence of 55.1% (n=43), 94.1% (n=16), and 66.6% (n=2), respectively.

Mean dmft: There was a total of 283 decayed, missing, and filled primary teeth; and the dmft was 2.89 ±3.06 for the full study group.

Mean dmft of Caries children (5.60 ±3.46) (95% CI: 7.52, 3.68) was higher than MIH children (2.44 ±2.79) (95% CI: 1.07, 1.80), and was lowest in AI children (1.00 ±1.00) (95% CI: 3.48, -1.48).

5.11.2.1 Difference in dmft between MIH and Caries groups

Mann-Whitney U test was run to determine if there were differences in dmft score between MIH and Caries children. Mean dmft for Caries children was statistically significantly higher than in MIH children, U =329 , z = -3.341, p = .001.

- *Decayed primary teeth*: Caries children had statistically significantly higher mean decayed primary teeth (3.40 ±3.52) than MIH children (1.67 ±2.35), U=428, z = -2.097, p < .036

- *Missing primary teeth*: Caries children had statistically significantly higher mean missing primary teeth (2.00 ±3.54) than MIH children (0.51 ±1.45), U=484, z = -2.439, p < .015.
- *Filled primary teeth*: MIH children has higher numbers of filled primary teeth (n=20; mean 0.26 ±0.90) than Caries children (n=3, mean 0.20 ±0.56), however they had similar means and there was no statistically significant difference found, U=581, z = -.061, p = .952.

5.11.3 DMFT/dmft and IMD quintiles

The association between deprivation quintile and mean DMFT/dmft was tested using a Spearman's rank-order correlation. There was a statistically significant positive relationship between mean DMFT (permanent teeth) and dmft (primary teeth) with IMD quintile, indicating the more deprived, the higher the mean DMFT/dmft ,(DMFT: rs = .398, p < .0005) (dmft: rs = .340, p < .001.).

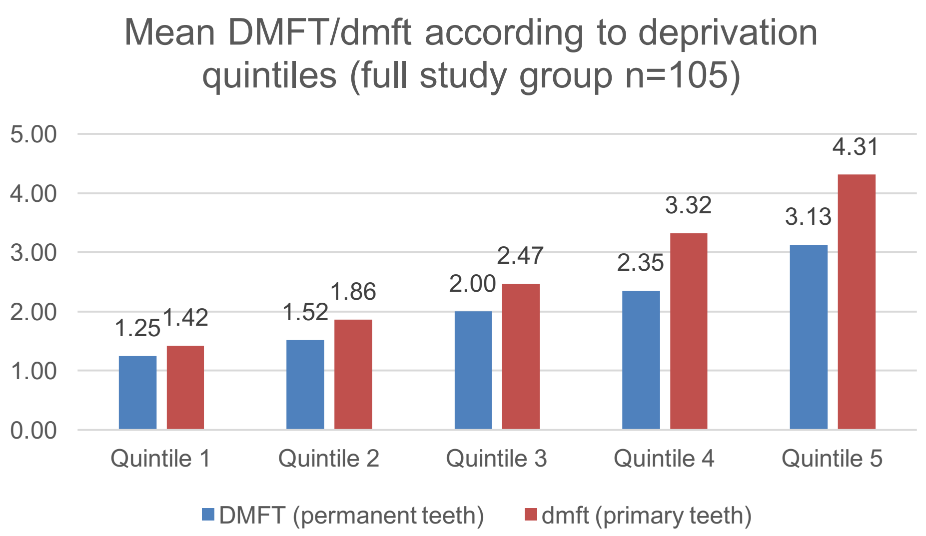


Figure 5-25: Mean DMFT according to IMD quintiles

5.12 Anomalies in the dentition

All recruited subjects in this study had their OPT radiographs and clinical photos assessed for presence other dental developmental anomalies. The assessments were made by the primary investigator [HB], later by an experienced orthodontist [JS] to verify findings and insure consistency. The following dental anomalies were assessed:

- Hypodontia of lateral incisor
- Hypodontia of premolar
- Mesiodens supernumerary
- Ectopic FPM
- Ectopic canine
- Impacted premolar
- Impacted incisor
- Infraoccluded primary molar
- Macrodont incisor

Of the 105 children in this study, 29 (27.6%) had at least one dental anomaly present (23 MIH group, 5 Caries group, 1 AI group). The children had a total of 56 teeth with a dental anomaly (43 MIH group, 11 Caries group, 2 AI group). Differences between the diagnosis groups and genders were investigated.

5.12.1 Number of anomaly types per child

The following results are presented by number of dental anomaly types per child:

- No anomaly
- 1 anomaly
- > 1 anomaly

Genders: Differences in the number of different types of dental anomalies between the genders were investigated by running a Mann-Whitney U test. There was no statistically significant difference between mean number of dental anomaly type per child in males (.38 ±.63) and females (.33 ±.62), $U = 1312$, $z = -.536$, $p = .592$.

Diagnosis: A Kruskal-Wallis H test was conducted to determine if there were differences the number of dental anomaly types per child between MIH (n=82), Caries (n=20), and AI(n=3) groups. Distributions were similar for all groups, as assessed by visual inspection of a boxplot. There was no statistically significant differences in Mean number of dental anomaly types between MIH (.37 ±.63), Caries (.30 ±.57), and AI (.33 ±.58) groups, $\chi2(2) = .127$ $p = .938$.

Table 5-11: Number of dental anomaly types per child, by diagnosis

Number of dental anomaly types per child	*MIH*	*Caries*	*AI*	*Total children (%)*
No anomaly	59 (71.9%)	15 (75%)	2 (66.6%)	76 (72.3%)
1 anomaly type	16 (19.5%)	4 (20%)	1 (33.3%)	21 (20.0%)
2 anomaly types	7 (8.5%)	1 (5.0%)	0 (0%)	8 (7.6%)
Total children	82 (100%)	20 (100%)	3 (100%)	105 (100%)

5.12.2 Dental anomalies (tooth-level)

Differences in number of teeth with dental anomalies (hypodontia of lateral incisor, hypodontia of premolar, mesiodens supernumerary, ectopic FPM, ectopic canine, impacted premolar, impacted incisor, infraoccluded primary molar) were investigated between the genders and between the diagnoses.

Genders: There were no statistically significant differences in mean number of teeth affected with each of the dental anomalies between males and females; as tested using Mann-Whitney U tests and displayed in Table 5-12.

Table 5-12: Number of teeth with dental anomalies by gender

	Total		*Genders: males (M) and females(F)*			*Statistic**	
	Number of teeth	Mean (± SD)		Number of teeth	Mean (± SD)	U statistic (z)*	P value*
Hypodontia of lateral incisor	14	.13 (± .48)	**F**	10	.19 (±.56)	1273 (-1.464)	.143
			M	4	.08 (±.38)		
Hypodontia of premolar	15	.14 (±.50)	**F**	2	.04 (±.19)	1244	.077
			M	13	.25 (±.68)	(-1.769)	
Mesiodens supernumerary	2	.02 (± .13)	**F**	1	.02 (±.14)	1377	.989
			M	1	.02 (±.14)	(-.014)	
Ectopic FPM	8	.08 (± .35)	**F**	4	.08 (±.39)	1355	.690
			M	4	.08 (±.33)	(-.014)	
Ectopic canine	8	.08 (± .33)	**F**	6	.12 (±.38)	1273	.096
			M	2	.04 (±.27)	(-1.665)	
Impacted premolar	4	.04 (± .27)	**F**	2	.04 (±.28)	1377	.989
			M	2	.04 (±.27)	(-.014)	
Impacted incisor	2	.02 (± .13)	**F**	0	0	1326	.159
			M	2	.04 (±.19)	(-1.408)	
infraoccluded primary molar	2	.02 (± .13)	**F**	0	0	1326	.159
			M	2	.04 (±.19)	(-1.408)	
Macrodont incisor	1	.01 (± .09)	**F**	0	0	1352	.322
			M	1	.02 (±.14)	(-.991)	

** Mann-Whitney U test*

Diagnosis: For each of the different anomalies, there was no statistically significant differences in mean number of affected teeth between MIH, Caries and AI groups, as per Kruskal-Wallis H tests (Table 5-13).

Table 5-13: Number of teeth with dental anomalies by diagnosis

	MIH group		*Caries group*		*AI group*		*Statistic**	
	Number of teeth	Mean (± SD)	Number of teeth	Mean (± SD)	Number of teeth	Mean (± SD)	χ2(2) H statistic*	P value*
Hypodontia of lateral incisor	10	.12 (±.45)	4	.20 (±.61)	0	.00	.445	.801
Hypodontia of second premolar	11	.13 (±.49)	2	.10 (±.44)	2	.67 (±1.15)	2.799	.247
Mesiodens supernumerary	2	.02 (±.15)	0	.00	0	.00	.566	.753
Ectopic FPM	8	.10 (±.40)	0	.00	0	.00	1.458	.482
Ectopic canine	5	.06 (±.87)	3	.15 (±.48)	0	.00	.996	.608
Impacted premolar	2	.02 (±.22)	2	.10 (±.44)	0	.00	1.278	.528
Impacted incisor	2	.02 (±.15)	0	.00	0	.00	.566	.753
Infraoccluded primary molar(E)	2	.02 (±.15)	0	.00	0	.00	.566	.753
Macrodont incisor	1	.01 (±.11)	0	.00	0	.00	.280	.869

** Kruskal-Wallis H test*

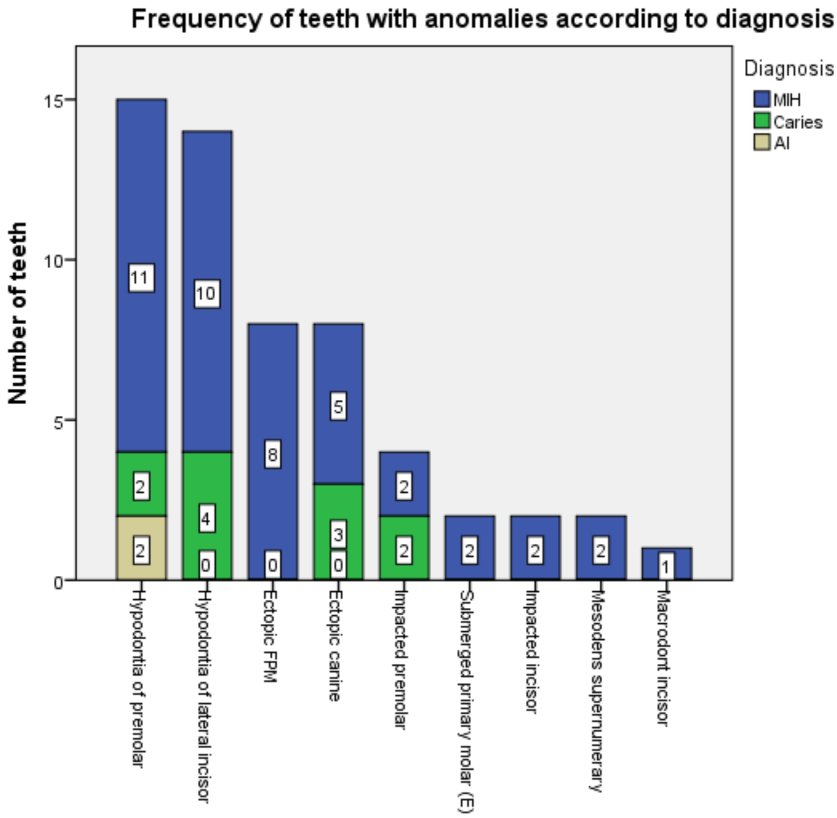


Figure 5-26: Distribution of number of teeth with dental anomalies, by diagnosis

5.12.3 Dental anomalies (child-level)

5.12.3.1 Hypodontia (developmentally absent permanent teeth)

There were 16 children affected with hypodontia of permanent lateral incisors or second premolars; one of whom had hypodontia of both tooth-types. The prevalence of children with hypodontia in the full study group was therefore 15.2% (7.6% lateral incisors, and 8.5% second premolars). Distribution and location of hypodontia for the full study group is presented in Table 5-14.

Table 5-14: Distribution, location, and prevalence of hypdontia in full study group of 105 children

Hypdontia *tooth type and location*		*Number of children (%)*	*Total (prevalence %)*
Lateral incisors	Upper	6 (5.7%)	8 (7.6%)
	Lower	2 (1.9%)	
	Upper + lower	0 (0.0%)	
Second premolars	Upper	2 (1.9%) *(2.8%)**	9 (8.5%)
	Lower	6 (5.7%) *(6.6%)**	
	Upper + lower	1 (0.9%)	

** Percentage prevalence includes the one child with hypodontia of both upper+lower second premolars*

5.12.3.2 Ectopic or impacted permanent teeth

Children in the full study group (n=105) had a 14.2% prevalence (n=15) of ectopic or impacted permanent teeth (FPM, canines, premolars, or incisors). Table 5-15 displays the distribution and prevalence of ectopic FPM, ectopic canines, impacted premolars, and impacted incisors in full study group.

Table 5-15: Distribution, location, and prevalence of ectopic and impacted permanent teeth in full study group (n=105)

Ectopic/impacted teeth *Tooth type and location*		*Number of children (%)*	*Total (prevalence %)*
Ectopic upper FPM	Unilateral	2 (1.9%)	5 (4.7%)
	Bilateral	3 (2.8%)	
Ectopic upper canine	Unilateral	4 (3.8%)	6 (5.7%)
	Bilateral	2 (1.9%)	
Impacted premolar	Upper	1 (0.9%)	2 (1.9%)
	Lower	1 (0.9%)	
Impacted incisor	Upper	2 (1.9%)	2 (1.9%)
	Lower	0 (0.0%)	

5.12.3.3 Mesiodens supernumerary

Two children from the study group had presence of a mesiodens supernumerary in the premaxilla, both of which were unerupted (1.9% prevalence).

5.12.3.4 Infraoccluded primary molar

Two children from the study group had a single infraoccluded second primary molar (1.9% prevalence); one child had it in the upper arch, and the other child in the lower arch.

5.12.3.5 Macrodont incisor

One child had a macrodont upper central incisor (0.9%).

Figure 5-27: A 7.9 year old girl (#073) with MIH displaying two types of anomalies: bilateral ectopic FPM and hypodontia of lower left lateral incisor; as evident in clinical photographs and OPT radiograph.

5.13 Clinician's judgement and planning

Clinicians responsible for the children's care at initial consultation judged many aspects of the patient including behaviour in the dental setting, oral hygiene status, and whether they had FPM symptoms. Clinicians also presented the agreed treatment plan for their patient, as well as the mode of treatment and whether or not an orthodontic consultation was taken into account. This was done in the form of a questionnaire specifically related to the child they had examined (Appendix 19). It took the clinicians anywhere from 2 to 10 minutes (average of 5.6 minutes) to fill out the questionnaire.

5.13.1 Behaviour in the dental setting

Behaviour in the dental setting was assessed by the clinician using the four-point Frankl (1962) behaviour rating scale, as explained earlier. Children in this study had predominantly definitely positive (++) behaviour (70%; n=74) , followed by 26.7% (n=28) with positive (+) behaviour, and only 2.9% (n=3) had negative (-) behaviour. There were no children who had definitely negative (- -) behaviour.

5.13.1.1 Frankl behaviour in MIH and Caries children

There was no statistically significant difference in Frankl behaviour scores of MIH and Caries children, as tested with a Mann-Whitney U test, U= 768, z= -.547 , p= .584.

5.13.1.2 Frankl behaviour and presence of dental anxiety

Children's Frankl behaviour rated by the clinician was found to be significantly associated with presence of dental anxiety (MCDASf ≥26), as displayed in Table 5-16, Fisher's exact test p=.002. Children with definitely positive behaviour (++) had significantly increased proportions of 'not anxious' (86.5%, adjusted residual +2.6) and significantly decreased proportions of 'anxious' (13.5%, adjusted residual -2.6). Conversely, children with negative behaviour (-) had significantly increased proportions of 'anxious' (100.0%, adjusted residual +3.5), and significantly decreased proportions of 'not anxious' (0.0%, adjusted residual -3.5). As for children rated has having positive behaviour (+), there was no statistically significant difference in proportions of 'anxious' and 'not anxious'.

Table 5-16: Cross-tabulation of Frankl behaviour and presence of dental anxiety

Frankl behaviour score	Dental anxiety		
	Anxious (total MCDASf ≥ 26)	*Not anxious (total MCDASf < 26)*	**Total**
Definitely positive (++)	10 13.5% **(-2.6)**	64 86.5% **(+2.6)**	74 100%
Positive (+)	8 28.6% (1.3)	20 71.4% (-1.3)	28 100%
Negative (-)	3 100.0% **(+3.5)**	0 0.0% **(-3.5)**	3 100%
Total	21	84	105

Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages

5.13.2 Oral hygiene status

Oral hygiene status was assessed by the child's clinician at initial consultation as good, fair, or poor. There was no clinician calibration carried-out for oral hygiene assessment, as it represented the clinician's view of the oral hygiene status. The majority of children's oral hygiene was rated as good (41.9%; n=44), followed by poor (37.1%; n=39), and fair (21.0%; n=22). Figure 5-28 shows the distribution of oral hygiene status of children in this study.

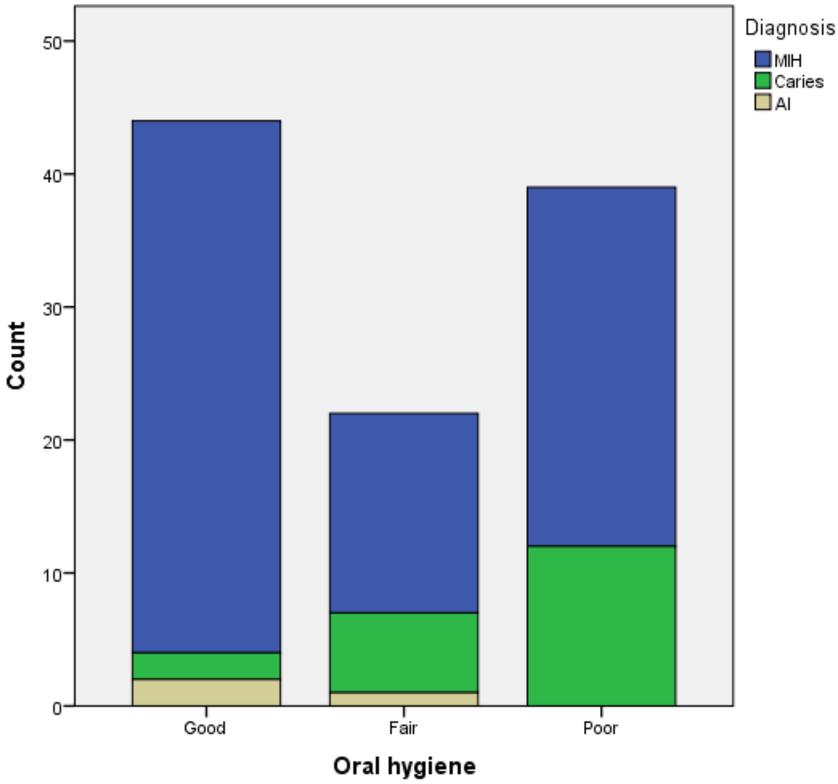


Figure 5-28: Distribution of oral hygiene status by diagnosis (n=105)

5.13.2.1 Oral hygiene status and diagnosis

Since AI group only has 3 subjects, no significant conclusions could be made with regards to difference in oral hygiene. Therefore, differences in children's oral hygiene was tested between MIH and Caries groups only.

A Mann-Whitney U test was run to determine if there were any differences in OH between MIH and Caries groups. Oral hygiene rating was significantly poorer in Caries children than MIH children, U= 493, z= -2.9 , p= .003.

Table 5-17: Oral hygiene status of MIH, Caries, and AI children

Oral hygiene	Diagnosis			Total
	MIH	*Caries*	*AI*	
Good	40 48.8%	2 10.0%	2 66.7%	44
Fair	15 18.3%	6 30.0%	1 33.3%	22
Poor	27 32.9%	12 60.0%	0 0%	39
Total	82 100%	20 100%	3 100%	105

5.13.3 Symptoms from FPM

Presence or absence of FPM symptoms at initial consultation (such as hypersensitivity or any other type of pain) was noted by the examining clinicians. Around half of the full study group (n=105) presented with FPM symptoms (52.4%; n=55), and half had no symptoms (47.6%; n=50).

5.13.3.1 FPM symptoms and diagnosis

There were no differences in proportions of reported presence of FPM symptoms between children in the MIH (n=44; 53.6%), Caries (n=10; 50.0%), or AI (n=1; 33.3%) groups, Fisher's exact test, p=.780.

5.13.3.2 FPM symptoms and Frankl behaviour

Presence or absence of FPM symptoms had no statistical significant affect or difference on children's behaviour rating, as tested with a Mann-Whitney U test, U= 1263, z= -.905 , p= .366.

5.13.3.3 FPM symptoms and severity by number of FPM affected

The mean number of affected FPM were similar in patients who had symptoms (3.18 ±.84) and those who had no symptoms (3.0 ± .97). There was no statistically significant association between the number of affected FPM and presence or absence of symptoms, as tested by a point-biserial correlation rpb= -.089, p= .365

5.13.4 Agreed treatment plan

Of the 105 children in this study, 23 (21.9%) were planned for FPM temporisation or review. The remaining 82 (78.0%) had a definite FPM treatment plan involving FPM restorations only (n=34), extractions only (n=31), or a combination of restorations and extractions (n=17).

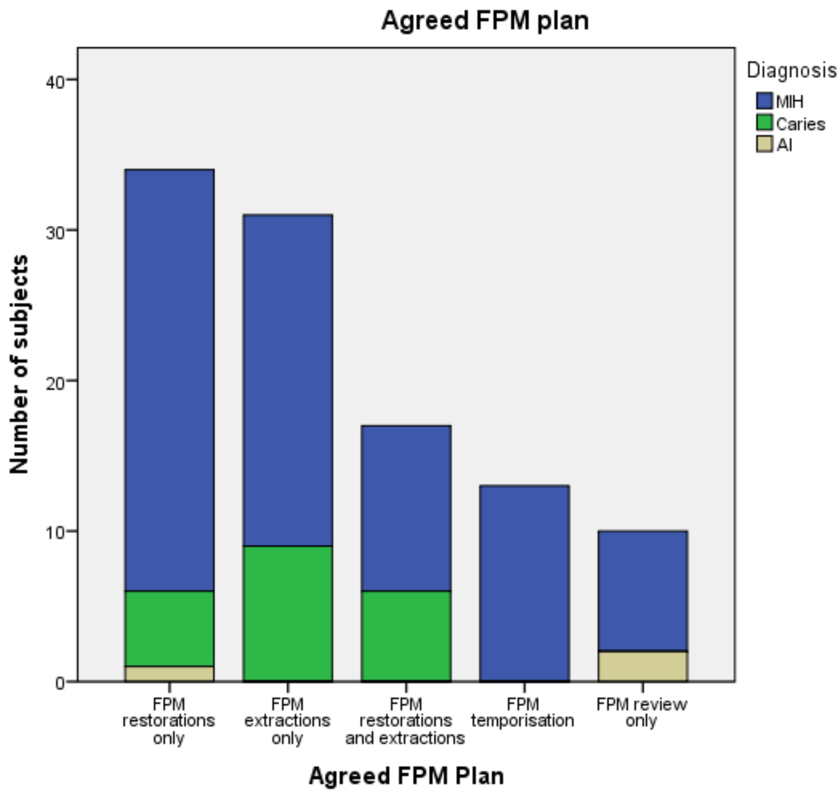


Figure 5-29: Distribution of agreed FPM plan by diagnosis (n=105)

5.13.4.1 Agreed treatment plan and diagnosis

There was a statistically significant difference in FPM treatment plans between children with different diagnoses as assessed by Fisher's exact test, p=.008. This significance was only of a valid degree in children with Caries diagnosis, who had significantly less FPM plans involving temporisation or review (n= 0; expected count= 4.4; adjusted residual -2.6). MIH and AI diagnosis did not show any significant deviations from expected count in types of FPM treatment plans; although a quarter of MIH children (n=21; 25.6%)) were planned for FPM temporization or review.

A Fisher's exact test was run again, with treatment plan categories combined into the FPM plan: 'involved FPM extraction', 'FPM restoration-only', and 'FPM review/ temporisation'. Statistically significant differences were found between MIH and Caries groups, p=.002. Caries children had significantly greater proportions of plans involving FPM extraction (75.0%; n=15; adjusted residual +2.9), whereas MIH children had significantly fewer proportions (40.2%; n=33; adjusted residual -2.1).

Caries group children also had statistically significantly fewer plans involving FPM temporisation/review (0%; n=0; adjusted residual -2.6).

5.13.4.2 Chronological and dental age on agreed treatment plan

The association between chronological age and dental age on FPM agreed treatment plan was tested using the eta (η) coefficient, which is a measure of association between a multinomial and continuous variable. It was run separately for testing association between chronological age with agreed plan; and again to test dental age with agreed plan.

Both chronological age and dental age had moderate associations with agreed plan, which were found statistically significant: Chronological age, eta $\eta = .389$, $p = .002$; Dental age, eta $\eta = .414$, $p = .001$.

Table 5-18: Mean chronological and dental ages with agreed FPM plan

Agreed FPM plan	Mean chronological age in years ±SD	Mean dental age in years ±SD	N
Extractions only	9.3 ±1.5	9.1 ±1.4	31
Restorations only	9.0 ±1.7	8.5 ±1.1	34
Extractions and restorations	9.9 ±1.0	9.3 ±0.6	17
Temporisation	7.8 ±0.7	7.7 ±0.4	13
Review only	8.7 ±1.0	8.4 ±0.8	10
Total	**9.0 ±1.5**	**8.7 ±1.1**	**105**

5.13.4.3 Agreed plan and lower SPM developing stage

A chi square test of independence was conducted between participants' lower SPM developing stage and agreed treatment plan. There was a statistically significant relationship between lower SPM developing stage and agreed treatment plan, $\chi 2$ $(8) = 26.430$, $p = .001$. The association was moderately strong, Cramer's V =.355.

The cross-tabulation in Table 5-19 displays frequencies with corresponding adjusted standardised residuals. It shows that participants with lower SPM developing stage E (initial calcification at bifurcation) had significantly more plans with FPM extractions than expected, whereas lower SPM stage D (crown completion to cemento-enamel junction) had significantly fewer plans involving FPM extractions. Table 5-19 also shows that participants with lower SPM developing stage D had significantly more FPM temporisation and reviews, whereas participants with stage E had significantly fewer plans involving temporisation or reviews. The other stages (C, F, and G) did not show any significant deviations from expected values; as evident from adjusted residuals not greater than 2 or less than -2.

Table 5-19: Cross-tabulation of lower SPM stage and agreed FPM plan

Agreed plan	Lower SPM developing stage					Total
	Stage C	*Stage D*	*Stage E*	*Stage F*	*Stage G*	
Plan involved FPM extraction	0 (-1.6)	8 **(-3.7)**	22 **(2.3)**	14 (1.7)	4 (1.1)	48
Plan involved FPM restoration (no extraction)	1 (0.0)	13 (0.4)	11 (-0.3)	7 (-0.2)	2 (0.1)	34
Plan involved FPM temporisation or review/FS	2 (1.9)	16 **(3.9)**	3 (-2.4)	2 (-1.7)	0 (-1.3)	23
Total	3	37	36	23	6	105
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies						

5.13.4.4 Agreed plan and Frankl behaviour

The relationship between children's Frankl behaviour score and agreed FPM plan was explored using Fisher's exact test (2xc), and a statistically significant difference was found, p= .041.

The relationship was only significant in 'extraction-only' FPM treatment plan. Children with negative Frankl behaviour (-) had significantly more 'extraction-only' FPM treatment plans (adjusted residual +2.7), whereas children with definitely positive Frankl behaviour (++) had significantly fewer 'extraction-only' FPM plans (adjusted residual -3.2).

There were no significant relationships found between Frankl behaviour score and the remaining FPM treatment plans: 'restoration-only', 'restoration and extraction', and 'temporisation/review'.

Table 5-20: Cross-tabulation of Frankl behaviour and agreed plan

Frankl behaviour score	Agreed FPM plan				Total
	Extractions only	*Restorations only*	*Restorations and extractions*	*Temporisation or review/ FS*	
Definitely positive (++)	15 20.3% **(-3.2)**	27 36.5% (1.4)	13 17.6% (0.6)	19 25.7% (1.4)	74 100%
Positive (+)	13 46.4% (2.3)	7 36.5% (-1.0)	4 14.3% (0.3)	4 14.3% (-1.1)	28 100%
Negative (-)	3 100% **(2.7)**	0 0% (-1.2)	0 0% (-0.8)	0 0% (-0.9)	3 100%
Total	31	34	17	23	105
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages					

5.13.4.5 Agreed plan and oral hygiene status

Children with plans involving FPM extractions (n=48) predominantly had poor OH (60.4%; n=29). As for children planned for FPM restorations only (i.e. no extractions), more than half had good OH (55.9%; n=19). Children planned for temporisation or review (n=23) also predominantly had good OH (69.6%; n=16).

A chi-square test of independence was conducted between child's oral hygiene and agreed treatment plan and there was a statistically significant association, $\chi 2(4) = 25.278$, $p < .0005$. The association between child's oral hygiene and agreed treatment plan was moderately strong (Cohen, 1988), Cramer's V = .347.

From the cross-tabulation in Table 5-21 it is clear that children with good OH had significantly fewer treatment plans involving FPM extractions (adjusted residual -4.4; less than half of expected value), whereas children with poor OH had significantly more treatment plans involving FPM extractions (adjusted residual +4.5). Children with poor OH also had significantly less pans involving FPM restoration-only (adjusted residual -2.4) and significantly less FPM temporisation or review (adjusted residual -2.7; a third of the expected value). Children with fair OH, did not show any specific deviation in FPM treatment plan from expected values.

Table 5-21: Cross-tabulation of oral hygiene and agreed treatment plan

FPM Plan	Oral hygiene			Total
	Good	*Fair*	*Poor*	
Plan involved FPM extraction	9 18.8% **(-4.4)**	10 20.8% (0.0)	29 60.4% **(4.5)**	48 100%
Plan involved FPM restoration (no extraction)	19 55.9% (2.0)	8 23.5% (0.4)	7 20.6% **(-2.4)**	34 100%
Plan involved FPM temporisation or review/FS	16 69.6% (3.0)	4 17.4% (-0.5)	3 13.0% **(-2.7)**	23 100%
Total	44	22	39	105
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages				

5.13.5 Mode of planned treatment

Of the 105 children in this study, 23 (21.9%) had no operative treatment planned, and therefore had no specific mode of treatment (GA, LA, IS, or combination). The remaining 82 children were predominantly planned for GA (n=38; 46.3%), followed by LA (n=30; 36.5%), IS (n=9; 10.9%), and combination of GA/LA/IS (n=5; 6.0%). The distribution of treatment modes are displayed in Figure 5-30.

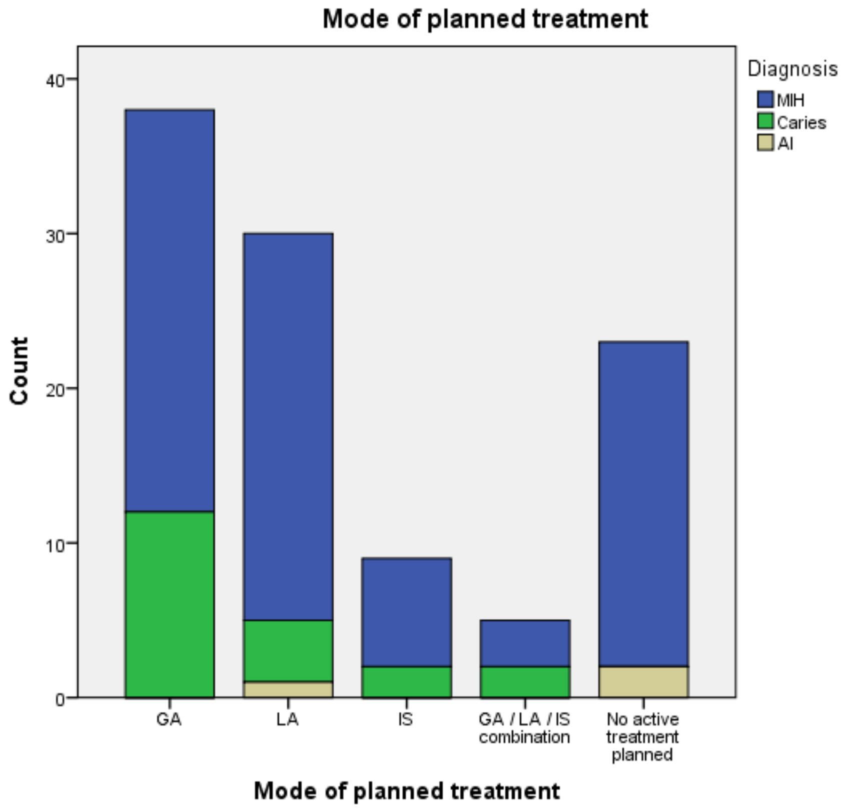


Figure 5-30: Mode of planned FPM treatment by diagnosis

5.13.5.1 Mode of planned treatment and diagnosis

There was a statistically significant difference in treatment mode of children with different diagnoses as assessed by Fisher's exact test, p=.008. This result was only valid in children with Caries diagnosis, who had significantly more treatment plans under GA (60%; n=12; adjusted residual +2.5). Caries children also had significantly less treatment plans with no treatment mode (ie no operative treatment plans) (n=0; adjusted residual -2.6). MIH and AI diagnoses did not show any significant deviations from expected counts in different treatment modes (GA, LA, combination GA/LA/IS).

5.13.5.2 Mode of treatment and oral hygiene

The association between the children's rated OH and the planned mode of treatment was tested using a chi-square test of independence, and a statistically significant association was found $\chi 2(4) = 21.399$, $p = .0006$; which was moderately strong, Cramer's V= .451.

Results reveal that 60.5% (n=23) of children planned for GA mode of treatment had poor OH. The adjusted residual was 3.7, indicating that children with poor OH were significantly more frequently planned for GA than expected.

Although 50% of the children that were planned for treatment under LA had good OH (n=15), the adjusted residual was only 1.1, indicating it was not significantly different than expected frequency.

About one-fifth of the children in this study, had no operative treatment planned (n=23) and therefore were not assigned a certain mode of treatment (operative treatment consists of having restorations/extractions under GA, LA, IS, or combination). Of these, 69.6% (n=16) had good OH, adjusted residual 3.0 indicating a significantly greater frequency than expected. The opposite was also true, where children with poor OH had significantly less plans with no operative treatment (about one-third of expected value).

For children with fair OH, there were no significant associations with planned treatment mode found. There were no significant relationships found between the treatment modes LA, IS, and combination GA/LA/IS with children having good, fair, or poor OH.

Table 5-22: Cross-tabulation mode of treatment and oral hygiene

Mode of treatment	**Oral hygiene**			**Total**
	Good	*Fair*	*Poor*	
GA	8 21.1% **(-3.3)**	7 18.4% (-0.5)	23 60.5% **(3.7)**	38 100%
LA	15 50.0% (1.1)	8 26.7% (0.9)	7 23.3% (-1.9)	30 100%
IS	4 44.4% (0.2)	2 22.2% (0.1)	3 33.3% (-0.2)	9 100%
GA/LA/IS combination	1 20.0% (-1.0)	1 20.0% (-1.0)	3 60.0% (1.1)	5 100%
No operative treatment planned	16 69.6% **(3.0)**	4 17.4% (-0.5)	3 13.0% **(-2.7)**	23 100%
Total	44	22	39	105
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages				

5.13.5.3 Mode of treatment and Frankl behaviour

The relationship between children's Frankl behaviour score and modes planned treatment was tested using Fisher's exact test (2xc), and a statistically significant difference was found in GA and LA modes of treatment, p= .038.

GA: Children with definitely positive Frankl behaviour (++) were significantly less frequently planned for treatment under GA (adjusted residual -3.5), while children with positive (+) and negative (-) Frankl scores were significantly more frequently planned for GA (adjusted residuals +2.7 and +2.3, respectively).

LA: Children with definitely positive (++) Frankl behaviours were significantly more frequently planned for treatment under LA (adjusted residuals +2.3).

There were no significant relationships found between children's Frankl behaviour ratings and the remaining planned modes of treatment ('IS' and 'no operative treatment planned).

Table 5-23: Cross-tabulation of Frankl behaviour and mode of treatment

Frankl behaviour score	**Mode of treatment**					**Total**
	GA	*LA*	*IS*	*GA/LA/IS combination*	*No operative treatment planned*	
Definitely positive (++)	19 25.7% **(-3.5)**	26 35.1% **(2.3)**	6 8.1% (-0.3)	4 5.4% (0.5)	19 25.7% (1.4)	74 100%
Positive (+)	16 57.1% **(2.7)**	4 14.3% (2.0)	3 10.7% (0.5)	1 3.6% (-0.3)	4 14.3% (-1.1)	28 100%
Negative (-)	3 100% **(2.3)**	0 0.0% (-1.1)	0 0.0% (-0.5)	0 0.0% (-0.4))	0 0.0% (-0.9)	3 100%
Total	38	30	9	5	23	105
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages						

5.13.5.4 Mode of treatment and severity by number of FPM affected

The association between mode of planned treatment and severity of disease by number of FPM affected was explored. The mean number of affected FPM in children planned under GA (3.13 ± 0.7) and LA (3.17 ±0.8) was more than children planned under IS (2.6 ± 1.0) and G/LA/IS combination (2.2 ± 1.0). However, there was no statistically significant association found, as tested by eta (η) coefficient, eta η = .292, p=.061.

5.13.6 Elective extractions

For children in this study, any FPM planned for extraction and evaluated by the clinician as *'sound'* or *'restorable with good long-term prognosis'* was regarded as an elective extraction. They were further categorised into the type of elective extraction such as compensation, balancing, and whether they were upper or lower FPM. Figure 5-31 displays the distribution of the types of elective extractions planned on children in this study. Of the 48 children that had FPM extraction in their treatment plan, 32 (66.6%) had no elective extractions planned; which means those FPM planned for extractions were evaluated as *'non-restorable with poor long term prognosis'* or *'restorable with questionable long-term prognosis'*. There were 16 children that had at least one elective FPM extraction in their treatment plan.

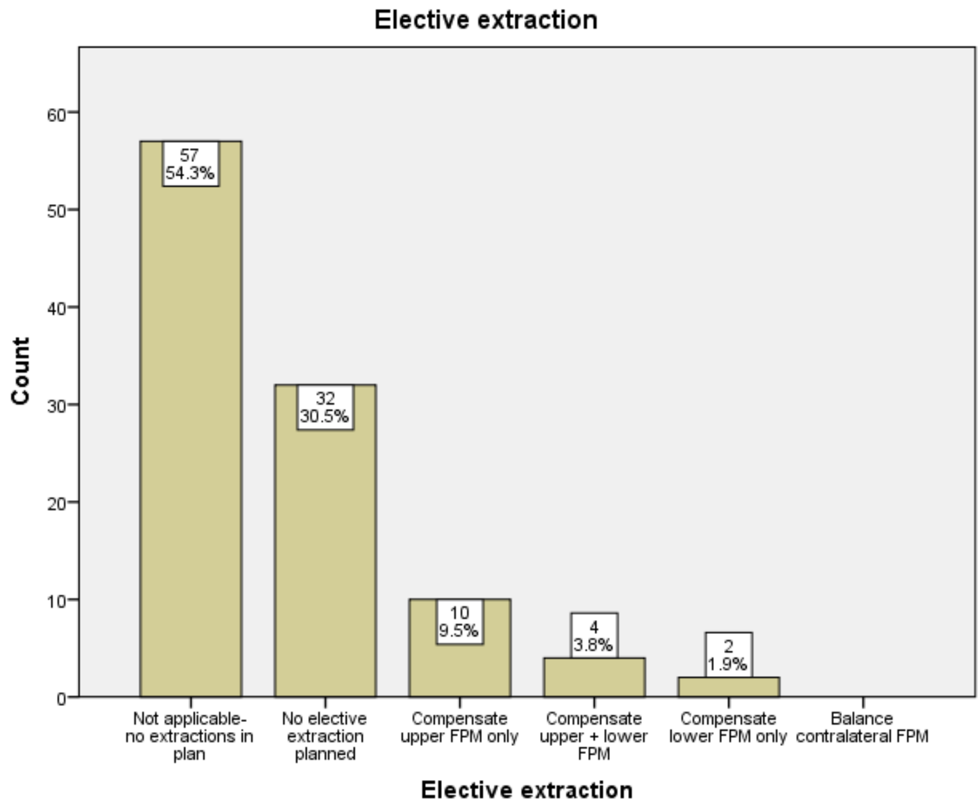


Figure 5-31: Distribution of the types of elective extractions planned (n=105)

5.13.6.1 Elective extractions and diagnosis

There was a statistically significant association between the planning of elective FPM extraction and diagnosis, as assessed by Fisher's exact test, $p = .003$.

Of the 16 children having one or more elective FPM extraction in their treatment plan, 50% (n=8) had MIH and 50% (n=8) had Caries. Although the numbers and percentages appear equal, there were significant deviations in expected frequencies, where elective FPM extractions were less than two-thirds the expected count for MIH children (expected count 12.5, adjusted residual -3.0) and more than double the expected count for Caries children (expected count 3, adjusted residual +3.4). There were no significant deviations in expected frequencies for AI children, which could be attributed to the small sample size (n=3).

Table 5-24: Elective extractions and diagnosis

Elective extraction		Diagnosis			Total
		MIH	*Caries*	*AI*	
Elective extraction	*Count (%)* *Expected count* *Adjusted residual*	8 (50%) 12.5 **-3.0**	8 (50%) 3.0 **+3.4**	0 0.5 -0.7	16 (100%)
No elective extraction	*Count (%)* *Expected count* *Adjusted residual*	25 (78.1%) 25.0 0.0	7 (21.9%) 6.1 +0.5	0 (0%) 0.9 -1.2	32 (100%)
Not applicable (no extractions in plan)	*Count (%)* *Expected count* *Adjusted residual*	49 (86%) 44.5 +2.1	5 (8.8%) 10.9 -2.9	3 (5.3%) 1.6 1.6	57 (100%)
Total		82	20	3	105
Note: Adjusted standardised residuals appear in the parentheses below observed frequencies and percentages					

5.13.6.2 Elective extractions and treatment mode

There was a statistically significant difference in proportions with planning of elective FPM extractions and mode of planned treatment, as assessed by Fisher's exact test, p<.0005. Of all the 16 children planned for elective extraction, 14 of them (87.5%) were planned for treatment under GA; which was more than double the expected frequency (expected count 5.8, adjusted residual +4.6). One child (6.3%) out of the 30 children planned for treatment under LA, had an elective FPM extraction, which was one-fifth of expected frequency (expected count 4.6, adjusted residual -2.1).

There were no other significant deviations from expected frequencies in elective extraction count for children planned for treatment under IS or a combination of GA/LA/IS.

5.13.7 Orthodontic opinion

Of the 105 children in this study, 31.4% (n=33) had an orthodontic opinion sought to confirm the agreed FPM plan, whereas 68.6% (n=72) did not have an orthodontic opinion.

5.13.7.1 Orthodontic opinion and diagnosis

The child's diagnosis (MIH, Caries, AI) had no statistically significant association on whether or not an orthodontic opinion was obtained, as tested with Fisher's exact test, p=.640.

5.13.7.2 Orthodontic opinion and type of treatment plan

The type of FPM treatment plan (extractions, restorations, review) had no statistically significant association with whether or not an orthodontic opinion was obtained, as tested with Fisher's exact test, p= .177.

5.13.7.3 Orthodontic opinion and mode of treatment

Mode of planned treatment (LA, IS, GA) had no statistically significant association with whether or not an orthodontic opinion was obtained, Fisher's exact test p=.692.

5.13.7.4 Orthodontic opinion and FPM elective extraction

Significant associations were found between FPM elective extractions and seeking an orthodontic opinion, as tested with Fisher's exact test. Interestingly, children with no elective extractions planned had significantly more opinions sought (45.5%; n=15; adjusted residual +2.3) than children who were planned for elective extraction (24.2%; n=8), p=.004. Children planned for FPM elective extractions however, had no association with whether or not an orthodontic opinion was sought; as 50% (n=8) had an opinion sought and 50% (n=8) did not.

When the different types of elective extractions were tested, a statistically significant association was found only with cases with lower FPM compensation planned. Those cases showed significantly increased frequency of seeking an orthodontic opinion (n=2; 100%; adjusted residual +2.1), p= .001. No significant associations were found with cases that had compensation of upper FPM, and combination of upper and lower FPM compensation.

5.13.7.5 Orthodontic opinion and severity by number of FPM affected

There was a small statistically significant correlation between disease severity by number of FPM teeth affected and whether or not an orthodontic opinion was obtained. A point-biserial correlation revealed that children with a higher number of affected FPM were less likely to get an orthodontic opinion rpb=.283, p= .003. Children needing an orthodontic opinion had significantly less mean affected FPM

(1.66 ± .46), compared to children that did not have an orthodontic opinion (3.10 ± .90).

5.14 Orthodontic features

Orthodontic features were assessed using a combination of orthodontic study models, clinical photographs, and OPT radiographs by the primary investigator [HB], and later by an experienced orthodontist [JS] to verify findings and insure consistency. To ensure reliability, measurements and assessment of randomly selected 26 children were repeated at least 3-4 weeks later, and confirmed again by the experienced orthodontist.

There were 6 children in the study group that did not have impressions for study models. Orthodontics features were therefore described in 99 children (77 MIH, 19 Caries, 3 AI).

5.14.1 Dental development stage

Children in the study were placed in one of three developmental stages: early mixed (incisors erupting), intermediate mixed (incisors fully erupted), and adolescent dentition (canines and premolars fully erupted). 64.6% of children were in the intermediate mixed (n= 64), followed by 27.2% in the early mixed (n=27), and 8.1% were in the adolescent dentition (n=8).

There were significantly more MIH children in the early mixed dentition (n=25; 92.5%) (adjusted residual +2.2) and more Caries children in the adolescent dentition (n=4; 50.0%) (adjusted residual +2.3), Fisher's exact test, p=.012. There were no other significant differences in developmental stages and diagnosis groups.

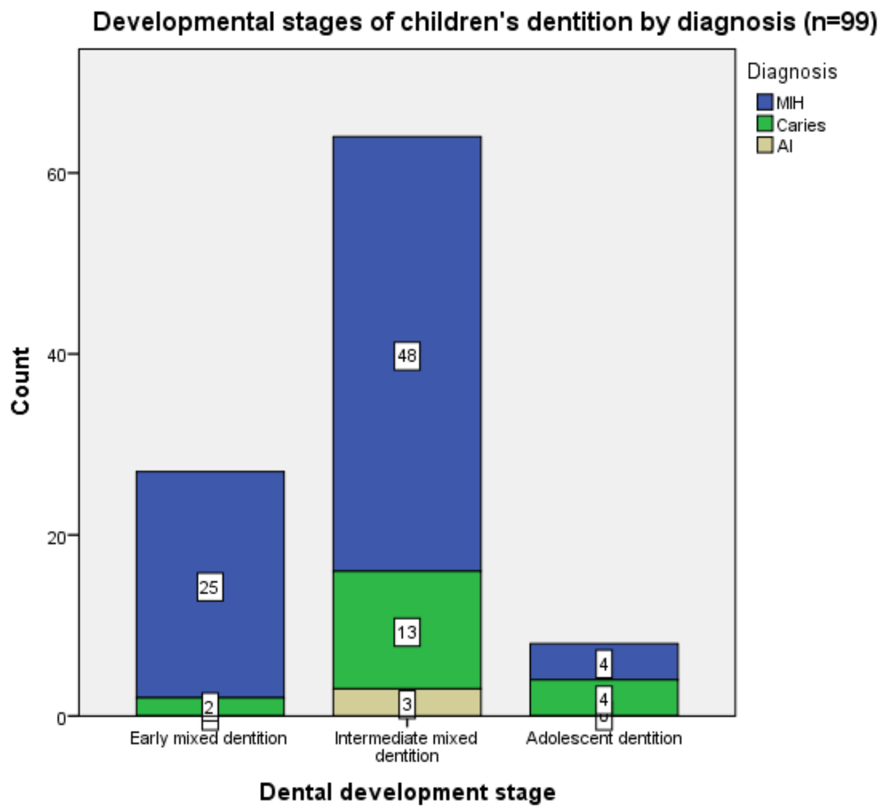


Figure 5-32: Distribution of dental developmental stages by diagnosis (n=99)

5.14.2 Orthodontic treatment need

The dental health component (DHC) of IOTN grades orthodontic need ranging from 5 'very great need' to 1 'no need'. Figure 5-33 displays distribution of orthodontic treatment need, by diagnosis. There were no statistically significant differences in orthodontic treatment need between MIH, Caries, and AI children, as per Fisher's exact test, p=.748.

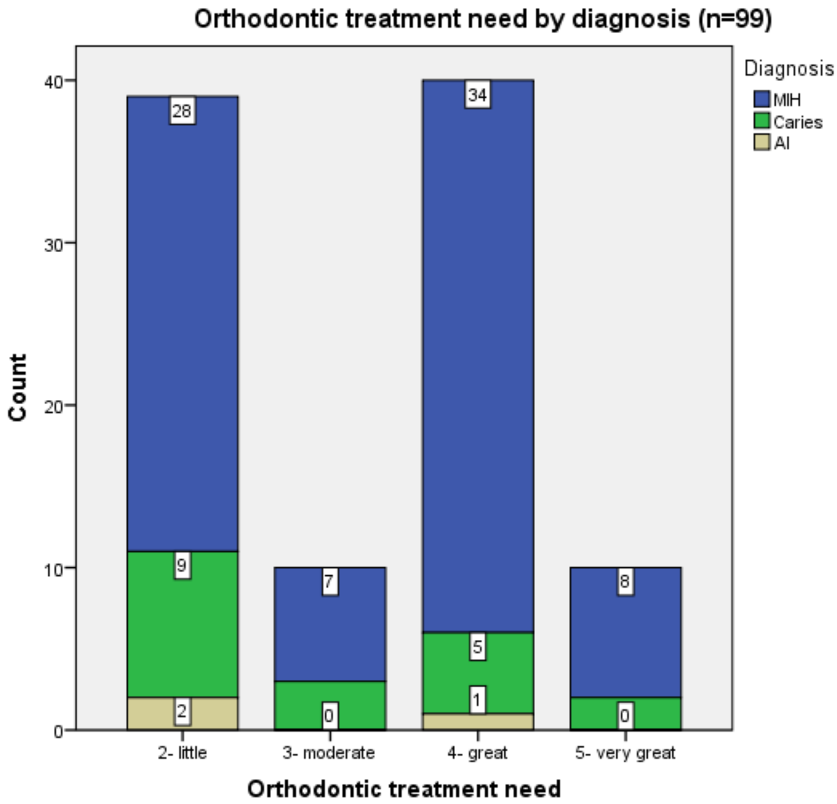


Figure 5-33: Orthodontic treatment need by diagnosis (n=99)

5.14.3 DHC deviant traits

The DHC of IOTN involved assigning the worst occlusal trait from a hierarchal scale (Figure 4-6). More than a quarter of children (27.3%; n=27) had good occlusion (2g). The remaining children's deviant traits included crossbite (19.2%; n=19), overjet (18.2%; n=18), hypodontia (10.1%; n=10), impeded eruption (8.1%; n=8), overbite (5.1%; n=5), crowding (5.1%; n=5), PE and impacted (3.0%; n=3), openbite (2.0%, n=2), reverse overjet (1.0%, n=1), and supernumerary teeth (1.0%; n=1).

There were no differences in DHC deviant occlusal traits between MIH, Caries, and AI children, Fisher's exact test, p= .441.

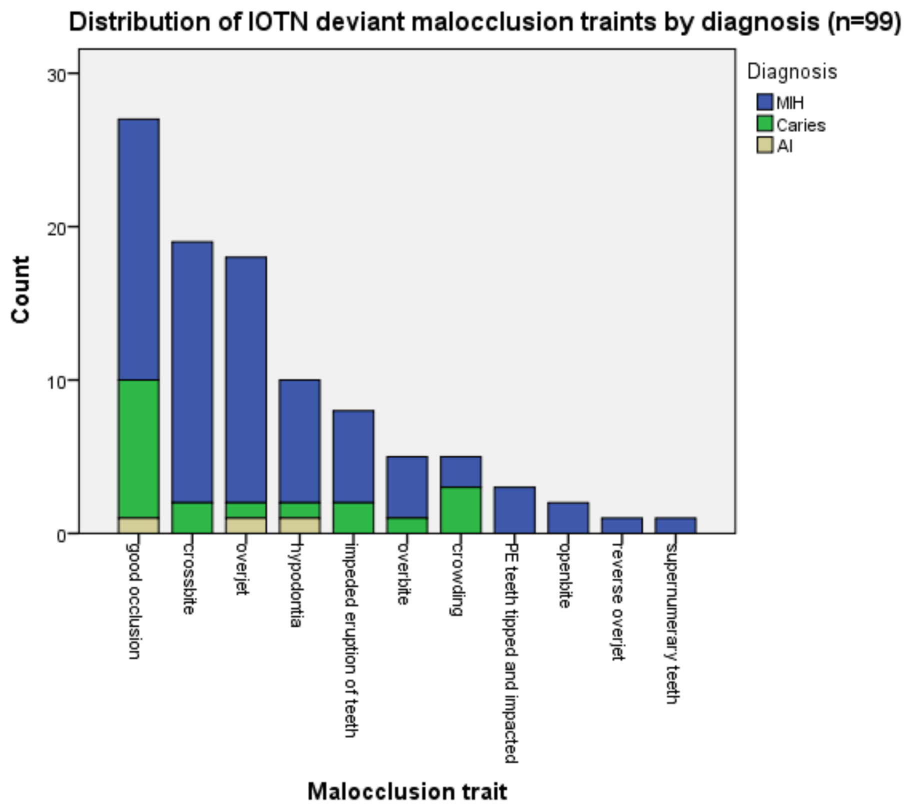


Figure 5-34: Distribution of children's deviant traits from DHC of IOTN according to diagnosis (n=99)

5.14.4 Assessment of occlusion

Parameters of occlusion that were assessed include skeletal pattern, molar relationship, incisor relationship, overjet/reverse overjet, dental crowding, overbite, openbite, centreline, and crossbite. Differences between MIH, Caries, and AI groups were also investigated using Fisher's exact test.

5.14.4.1 Skeletal pattern

Over half of the children had a skeletal class I relationship (56.5%; n=56), followed by class II (25.2%; n=25), and Class III (18.2%; n=18). There were no statistically significant differences in skeletal pattern between MIH, Caries, and AI children, p=.320 (Table 5-25).

5.14.4.2 Molar relationship

Right and left molar relationships were assessed and classification recorded. Some children could not have their molar relationship assessed on one side due to FPM too broken down or not present (right n=5; left n=3).

More than half of right and left molar relationships were ½ unit class II (right 57.4%; left 53.1%), followed by class I (right 24.4%, left 30.2%), full unit class II (right 153.9%; left 12.5%), and class III (right 2.1%; left 4.1%). There were no statistically significant differences between molar relationships of MIH, Caries, and AI children, as shown by the p values in Table 5-25.

5.14.4.3 Incisor relationship

Incisor relationship was assessed in all children with study models (n=99), except 2 who had unerupted or partially erupted central incisors. The majority of children had class II div1 incisor relationship (n=40; 40.4%), followed by class I (n=29; 29.3%), Class II div2 (n=17; 17.2%), and Class III (n=11; 11.1%). There was a statistically significant difference in children with class I, where Caries group had higher frequency (n=10; 52.6%; adjusted residual +2.5) and MIH group had lower frequency (n=17; 22.1%; adjusted residual -3.0), p=.048. There were no statistically significant differences between the other incisor classifications and diagnoses groups (Table 5-25).

Table 5-25: Distribution of skeletal, molar and incisor classification in MIH Caries and AI children

Angle's classification	*Total (%)*	*MIH*	*Caries*	*AI*	*P value **
Skeletal pattern (n=99)					
Class I	56 (56.5)	43	11	2	.320
Class II	25 (25.2)	18	7	0	
Class III	18 (18.2)	16	1	1	
Right molar relationship (n= 94)					
Class I	23 (24.4)	17	5	1	.737
½ unit class II	54 (57.4)	43	9	2	
Class II	15 (15.9)	11	4	0	
Class III	2 (2.1)	1	1	0	
Left molar relationship (n= 96)					
Class I	29 (30.2)	23	6	0	.894
½ unit class II	51 (53.1)	38	10	3	
Class II	12 (12.5)	9	3	0	
Class III	4 (4.1)	4	0	0	
Incisor relationship (n=97)					
Class I	29 (29.8)	17	10	2	.048
Class II Div 1	40 (41.2)	35	5	0	
Class II Div 2	17 (17.5)	12	4	1	
Class III	11 (11.3)	11	0	0	

**Fisher's exact test*

5.14.4.4 Overjet and reverse overjet

Table 5-26 shows presence and severity of overjet and reverse overjet in children (n=97, as 2 children had unerupted or partially erupted incisors). More than half of children had no increased overjet (n=55; 56.7%), followed by mild overjet (n=23; 23.7%), moderate (n=6; 6.1%), and severe (n=2; 2.0%). There were 7 (7.2%) children with edge to edge incisors and only 4 (4.1%) children with reverse overjet (mild n=2; moderate n=2). There were no statistically significant differences in overjet and reverse overjet between MIH, Caries, and AI children, p >.05.

Table 5-26: Distribution of overjet and reverse overjet in children with MIH, Caries, and AI (n=97)

Variable	*Total (%)*	*Diagnosis*			*P value **
		MIH	Caries	AI	
Overjet:					
No increased overjet	55 (56.7)	37	16	2	.184
Mild	23 (23.7)	21	1	1	
Moderate	6 (6.1)	5	1	0	
Severe	2 (2.0)	1	1	0	
Reverse overjet:					
Edge to edge	7 (7.2)	7	0	0	.882
Mild	2 (2.0)	2	0	0	
Moderate	2 (2.0)	2	0	0	
*TOTAL***	97 (100)	75	19	3	

** Fisher's exact test*
*** 2 children could not be assessed for OJ/reverse OJ due to PE or UE incisors.*

5.14.4.5 Dental crowding

For children in the permanent or late mixed dentition (premolars erupted) (n=8) crowding was assessed as per IOTN (2d- mild; 3d- moderate, 4d- severe). Children in the mixed dentition with premolars not yet erupted (n=92) had crowding assessed based on sufficient or insufficient space for tooth eruption (predicted crowding, no predicted crowding), as previously described.

For crowding in the mixed dentition, Caries group had statistically significantly more frequency of predicted crowding (n=7; adjusted residual +2.7), whereas MIH children had significantly more cases of ‘no predicted crowding’ (n=62; adjusted residual +2.7), p=.016.

For crowding in the permanent dentition, Caries group children showed more frequency of moderate (n=2; adjusted residual +2.9) and severe crowding (n=1; +2.1) than MIH (n=0) children. There was no significant difference between other crowding severities and diagnoses.

Table 5-27: Distribution of crowding severities in MIH, Caries, and AI children (n=99)

Crowding	*Total (%)*	*Diagnosis*			*P value **
		MIH	Caries	AI	
Permanent dentition (n=8):					
No crowding	4 (4.0)	3	1	0	
Mild	1 (1.0)	1	0	0	
Moderate	2 (2.0)	0	2	0	
Severe	1 (1.0)	0	1	0	.016
Mixed dentition: (n=92):					
No predicted crowding	73 (73.7)	62	8	3	
Predicted crowding	18 (18.1)	11	7	0	
TOTAL	99 (100)	75	19	3	

** Fisher's exact test*

5.14.4.6 Openbite (anterior and posterior)

Presence of anterior and posterior open bite was assessed as per IOTN (2e- mild; 3e- moderate; 4e- severe). Two children could not have anterior openbite assessed due to UE or PE incisors.

There were 13 (13.4%) children with an anterior openbite (n=11 mild, n=2 severe); however the majority had no anterior openbite (n=84; 86.5%). Only 3 children had a posterior openbite and they were all mild (3.0%). There were no statistically significant differences in anterior and posterior openbite between MIH, Caries, and AI children (p >0.05) (Table 5-28).

Table 5-28: Distribution of anterior and posterior openbite in MIH, Caries, and AI children

Openbite	*Total (%)*	*Diagnosis*			*P value **
		MIH	Caries	AI	
*Anterior openbite:***					
No openbite	84 (86.5)	63	18	3	
Mild	11 (11.3)	10	1	0	.864
Moderate	0	0	0	0	
Severe	2 (2.0)	2	0	0	
TOTAL:**	**97 (100)**	**75**	**19**	**3**	
Posterior openbite:					
No openbite	96 (96.9)	74	19	3	
Mild	3 (3.0)	3	0	0	1.000
Moderate	0	0	0	0	
Severe	0	0	0	0	
TOTAL:	**99 (100)**	**75**	**19**	**3**	

** Fisher's exact test*
*** 2 children could not be assessed for anterior openbite due to PE or UE incisors.*

5.14.4.7 Overbite

Overbite was assessed as per ICON as decreased, average, or increased as preciously described. The 2 children with UE or PE central incisors could not be assessed for overbite. The majority of children had an average overbite (n=45; 46.3%), followed by decreased (n=21; 21.6%) and increased (n=16; 16.4%). There were no statistically significant differences in overbite between MIH, Caries, and AI children, Fisher's exact test, p=.473.

5.14.4.8 Centrelines

Centrelines were assessed as per PAR (0- coincident; 1- deviation ¼ to ½ of lower incisor; 2- deviation > ½ of lower incisor). More than half of children had coincident centrelines (n= 56; 66.5%), and 34.4% (n=35) had grade 1 deviation, whereas only 8.1% (n=8) had grade 2 deviation. There was no statistically significant difference in centrelines between MIH, Caries, and AI groups, Fisher's exact test, p=.252.

5.14.4.9 Crossbite (anterior and posterior)

Presence of anterior and posterior crossbites were assessed as per ICON, and further classified into involvement of permanent/primary teeth, single/multiple teeth, and unilateral/bilateral; as appropriate.

The majority of children did not have an anterior crossbite (n=81; 81.8%). Of the 18 (18.1%) children with anterior crossbite, 10 (10.1%) involved permanent teeth (single tooth n=5; multiple teeth n=5) and 8 (8.0%) involved primary teeth. Posterior crossbite was not present in 81 children (81.1%). Of the 18 (18.1%) children with a posterior crosssbite, 12 (12.1%) were unilateral, 3 (3.0%) were bilateral, and 3 (3.0) involved primary teeth.

There were no statistically significant differences in anterior and posterior cross bite between MIH, Caries, and AI groups, as tested by Fisher's exact test and displayed in Table 5-29.

Table 5-29: Distribution of anterior and posterior crossbite in MIH, Caries, and AI children (n=99)

Crossbite	*Total (%)*	*Diagnosis*			*P value **
		MIH	Caries	AI	
Anterior crossbite:					
No crossbite	81 (81.1)	61	17	3	.729
Single tooth	5 (5.0)	3	2	0	
Multiple teeth	5 (5.0)	5	0	0	
Primary teeth	8 (8.0)	8	0	0	
TOTAL:*	**97 (100)**	**75**	**19**	**3**	
Posterior crossbite:					
No crossbite	81 (81.1)	61	18	2	.412
Unilateral	12 (12.1)	11	0	1	
Bilateral	3 (3.0)	2	1	0	
Primary teeth	3 (3.0)	3	0	0	
TOTAL	**99 (100)**	**75**	**19**	**3**	

** Fisher's exact test*
*** 2 children could not be assessed for anterior crossbite due to PE or UE incisors.*

5.14.5 Association between children's orthodontic features and seeking an orthodontic opinion

Fisher's exact test was used to test the associations between different orthodontic features and whether or not an orthodontic opinion was sought; and significant associations were found with orthodontic treatment need and anterior openbite.

Orthodontic treatment need: Children with grade 2 little orthodontic need (n=39) had significantly less frequent orthodontic opinions sought (n=7; 17.9%; adjusted residual -2.5); and children with grade 3 moderate (n=10) had significantly more frequently orthodontic opinions sought (n=7; 70.0%; adjusted residual +2.7), Fisher's exact test p=.013. Surprisingly, there was no significant association found with grade 4 great need and grade 5 very great need with seeking an orthodontic opinion.

Anterior open bite: Children with a severe anterior openbite had statistically significant increase in proportions of having an orthodontic opinion sought (n=2; 100%; adjusted residual +2.1), Fisher's exact test p=.045. There was no significant difference in proportions with other anterior openbite severities.

There were no significant associations found with other orthodontic features, including dental development stage (p=.412), DHC deviant trait (p=.082), skeletal pattern (p=1.00), molar relationship (right p=.636; left p=.497), incisor relationship (p=.502), overjet (p=.568), reverse overjet (p=.637), crowding (p=.504), posterior openbite (p=.695), overbite (p=.381), anterior crossbite (p=.654) posterior crossbite and centreline (p=.246).

5.14.6 Association between children's orthodontic features and FPM treatment plan

Fisher's exact test was used to test the associations between different orthodontic features and FPM treatment plan; and significant associations were found with dental development stage, skeletal pattern, and DHC deviant trait.

Dental development stage: Children in the early mixed dentition (n=27) had statistically significantly fewer proportion of FPM extraction in their treatment plans (n=5; 18.5%; adjusted residual -3.2), Fisher's exact test p=.010. There were no significant associations found between FPM plans with intermediate mixed or adolescent dentitions.

Skeletal pattern: Children with Class I skeletal pattern (n=56) had statistically significantly increased proportions of FPM plans involving FPM extraction (n=31; 55.3%; adjusted residual +2.5); while children with Class II skeletal pattern (n=25) had significantly increased proportions of FPM plans involving restoration-only (n=14; 56.0%; adjusted residual +2.8), Fisher's exact test p=.038. There were no significant associations found in plans involving FPM temporisation/review and skeletal pattern; as well as no association between class III and FPM treatment plan.

DHC deviant trait: A statistically significant association was found between children's DHC deviant trait and FPM plan. This association was only significant in the trait crowding (d), where 100% (n=5) of children with that DHC trait had treatment plans involving FPM extractions (adjusted residual +2.5), Fisher's exact test p=.045. No significant associations were found between FPM plan and the remaining 10 deviant traits found in children in this study.

There were no significant associations found between FPM plan and other orthodontic features, including orthodontic treatment need (p=.158), molar relationship (right p=.538; left p=.075), incisor relationship (p=.060), overjet (p=.196), reverse overjet (p=.309), crowding (p=.222), anterior openbite (p=.509) posterior openbite (p=.597), overbite (p=.491), anterior crossbite (p=.913) posterior crossbite (p=.692) and centreline (p=.163).

5.15 Factors influencing clinician's planning of the 105 children in this study

For each of the 105 children in this study, the clinician involved in their assessment at initial consultation had filled-out a questionnaire, specifically related to their subject patient (Appendix 19) involving different aspects of the child's diagnosis and planning, which included noting the factors that they found most important when deciding on the child's treatment plan. This was one way to investigate variables affecting treatment planning of children with poor quality FPM, as all children in this study had one or more affected FPM that required planning and management.

The clinician's responses were coded into 25 factors, as previously described (Figure 4-4). The primary factor affecting the children's (n=105) planning was FPM restorability (n=62; 59%), followed by patient behaviour/cooperation (n=52; 49.5%), presence of symptoms (n=41 ;39.0%), FPM severity or breakdown (n=31 ;29.5%) and FPM long term prognosis (n=25; 23.8%). Distribution of the remaining 20 factors is displayed in Figure 5-35.

There were no statistically significant differences in variables affecting treatment planning between MIH, Caries, and AI children, p>.05.

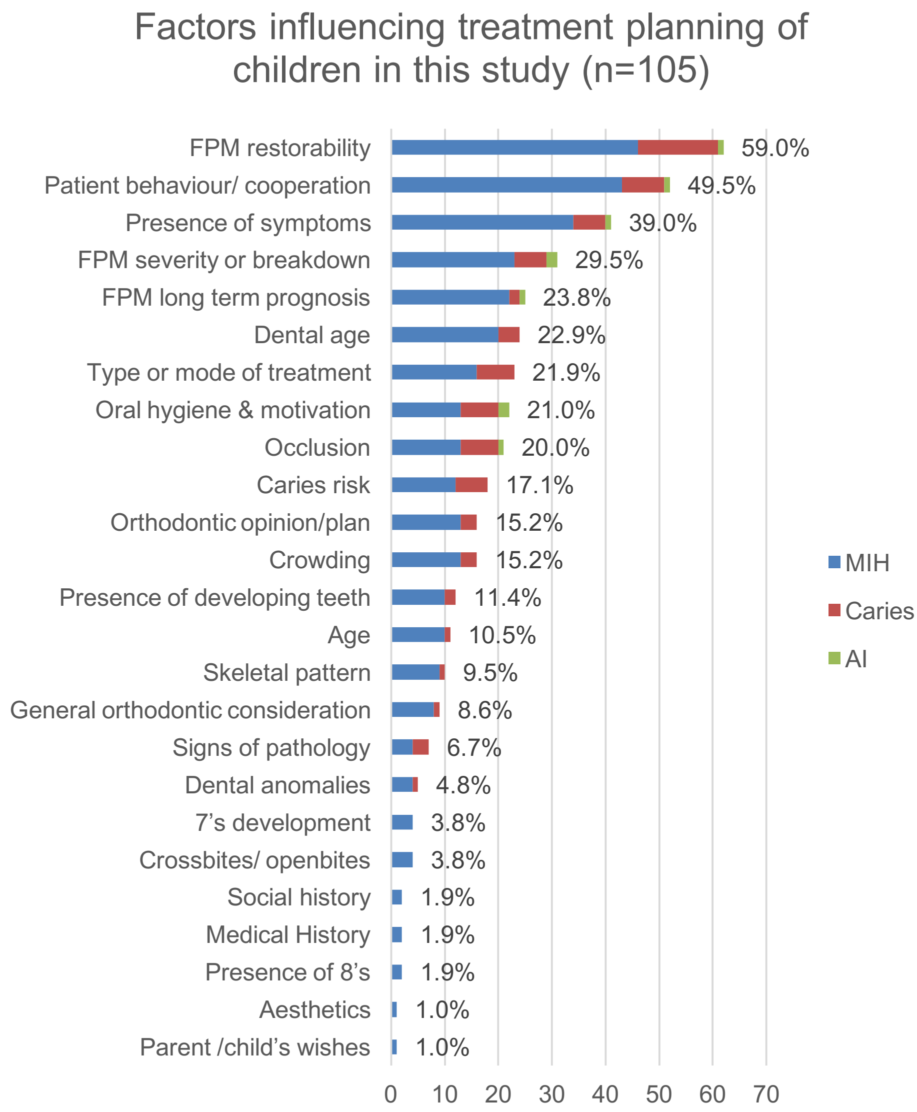


Figure 5-35: Factors affecting clinician's treatment planning of the 105 children in this study

5.16 Web-based survey – Paediatric dental clinicians

A web-based survey aiming to investigate treatment planning decisions and awareness of the RCS guidance on FPM extractions, was sent to paediatric dental clinicians in the Leeds Dental Institute and the Yorkshire and Humber Paediatric Clinical Network group. Responses were collected from November 2015 to March 2016, with 41 responding, giving a total response rate of 74.5%. Figure 5-36 shows the distribution of positions of clinicians who took part in the survey; and Figure 5-37 shows the distribution of years qualified as a specialist paediatric dentist.

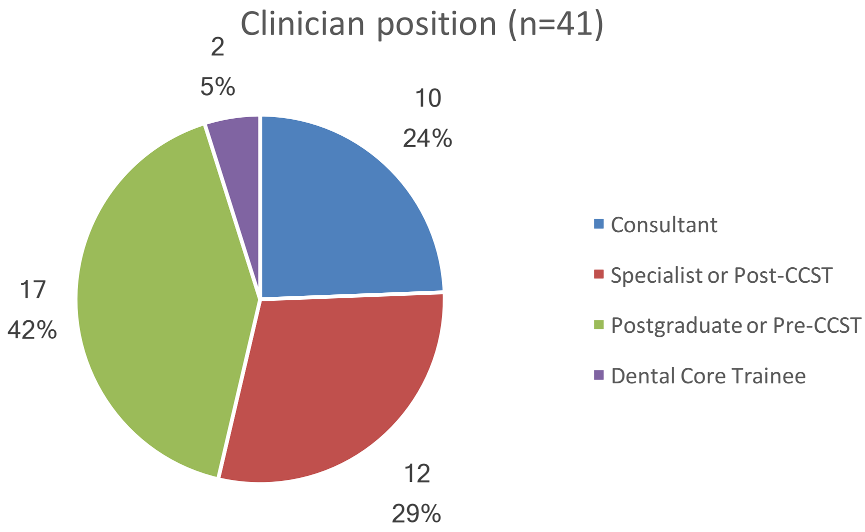


Figure 5-36: Clinician positions of those who took part in the web-based survey (n=41)

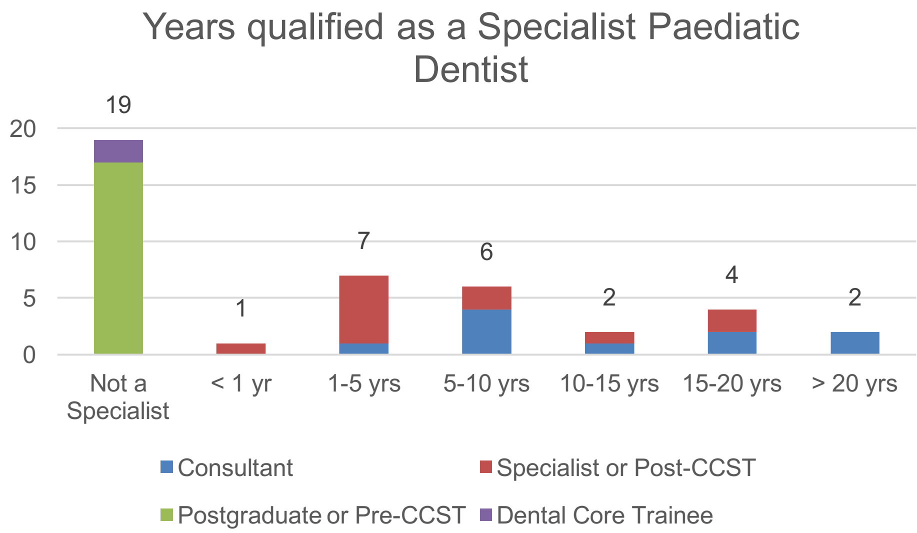


Figure 5-37: Distribution of clinicians' years qualified as a specialist paediatric dentist

5.16.1 Factors influencing clinician's planning of children with poor quality FPM (from web-based survey)

This section of the study investigated what variables clinicians generally take into account when treatment planning children with poor quality FPM. Factors associated with specific patients were explored in the previous section from clinicians of the 105 children in this study. The web-based survey however, also explored the general variables clinicians consider when making FPM planning decisions.

The responses were coded into 20 factors. The most commonly cited factor mentioned was patient behaviour/cooperation (n=31; 75.6%), closely followed by FPM restorability (n=29; 70.7%), presence of developing teeth (n=27; 65.8%), and dental age (n=26; 63.4%). Distribution of the remaining factors are shown in Figure 5-38.

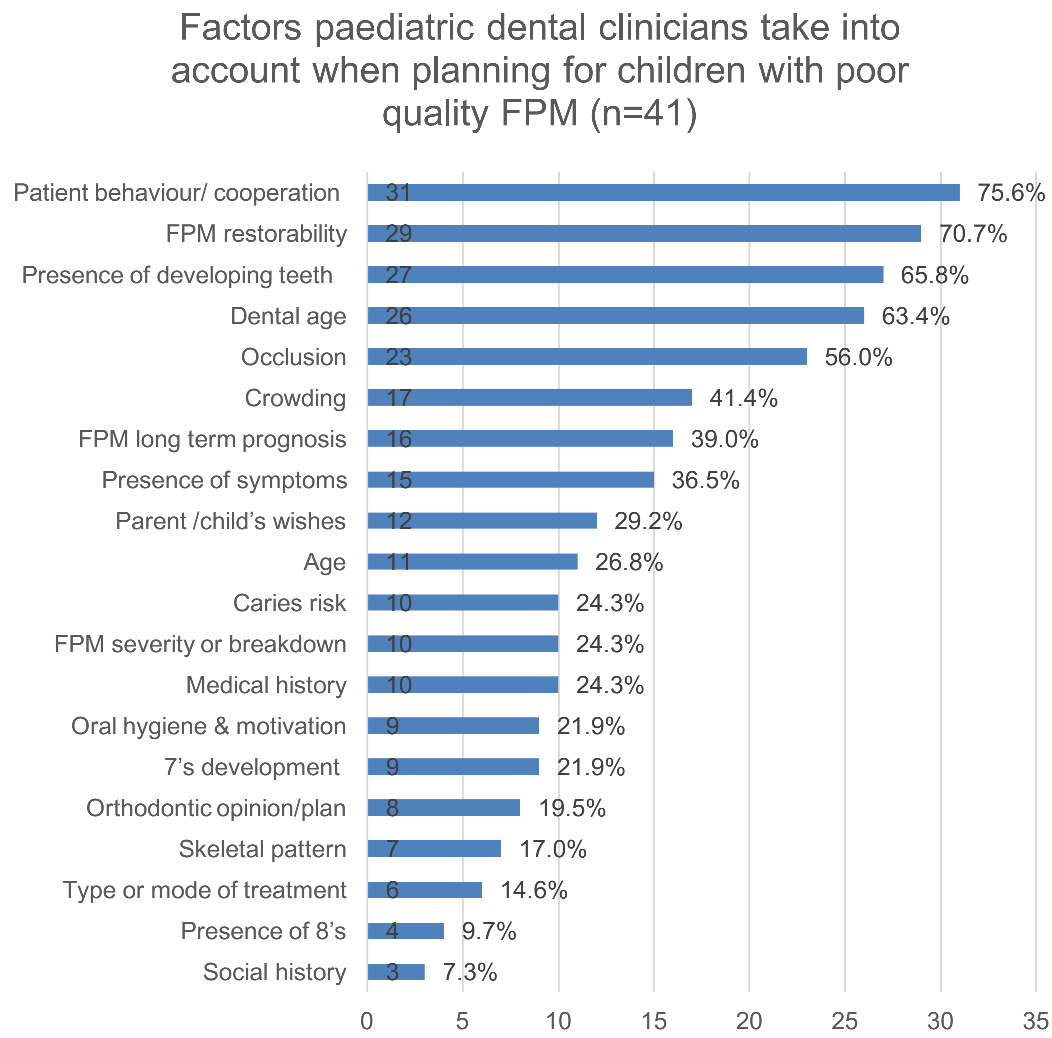


Figure 5-38: Factors influencing paediatric clinicians' decisions when planning for children with poor quality FPM (from 41 respondents of a web-based survey)

5.16.2 Consideration of the RCS guidance

One of the aims of the survey was to assess paediatric dental clinician's awareness and attitudes of the UK guidance, which offers advice on FPM extractions in children (Cobourne et al., 2014). Of the 41 clinicians that participated, 4 (9.7%) clinicians would not take into account a particular guidance, including 2 dental core trainees, 1 postgraduate or pre-CCST, and 1 consultant. The vast majority however (n=37; 90.2%) would take into account a particular guidance when making decisions involving FPM planning, all of which stated the RCS guidance when prompted for the guidance name. When asked about the year of guidance publication, 10 (27.0%) stated the 2009 former guidance, and 27 (72.9%) stated the 2014 latest guidance (one of whom stated the latest guidance as 2015).

Those 37 clinicians were further asked if they would always follow the guidance, where 17 (45.9%) said they would and 20 (54.0%) said they would not. Breakdown of the clinicians is shown in Figure 5-39.

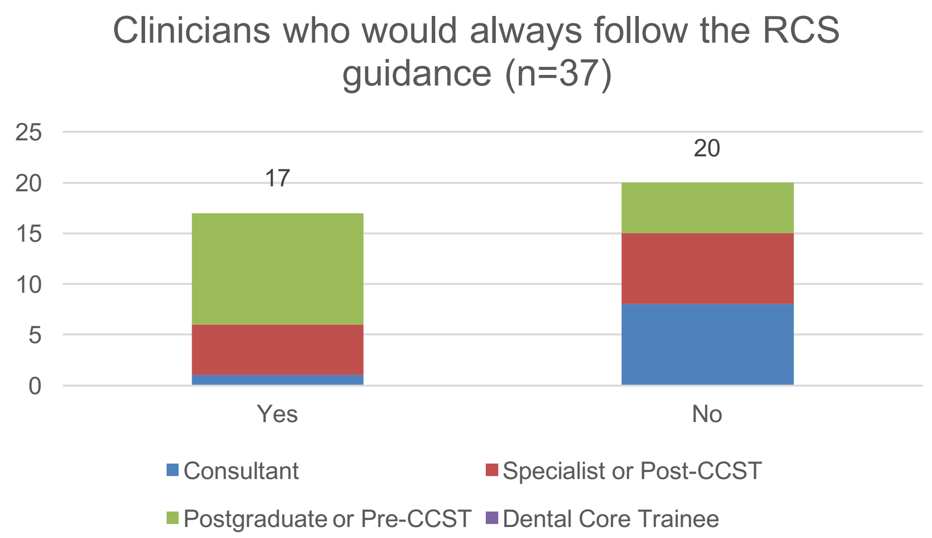


Figure 5-39: Breakdown of clinicians that would or would not always follow the RCS guidance (n=37)

5.16.3 When would clinicians not follow the guidance?

The clinicians that stated they would not always follow the guidance (n=20) were further asked in an open-ended question, in what instances would they not follow it. Their answers were coded and are presented in the following themes, ranked in order of frequency mentioned:

1. When orthodontic advice varies from the guidance.
2. When there is pain, requiring FPM extraction earlier than ideal age.
3. When there are abnormalities of dental development such as hypodontia.
4. When patient’s cooperation and parent wishes influence treatment plan.
5. When the child has special needs or complexities in the medical history.

6. When treatment plan is under GA, FPM extractions are favourable to avoid repeat GA.

Below, are examples of some clinician's comments regarding following the guidance:

> *"I see a lot of children with very high caries risk status where it is clear that a simple treatment plan of extractions followed by prevention is the best option and this overrides other considerations such as orthodontic status."*

> *"I almost always follow the guidance but occasionally there may be extenuating circumstances that would make you need to deviate from the guidance such as medical history, late presentation (ie after 7's erupted) when a discussion has to be made regarding possible compromises."*

5.16.4 Usefulness of the guidance and robustness of the evidence behind it

The 37 clinicians who stated they would take a particular guidance into account were further asked about how practically useful they found the guidance. Over half of the clinicians found it moderately useful (n=19; 51.3%), followed by extremely useful (n=17; 45.9%). There was 1 clinician (consultant) who stated that the guidance was not at all useful. Breakdown of the clinicians are shown in Figure 5-40.

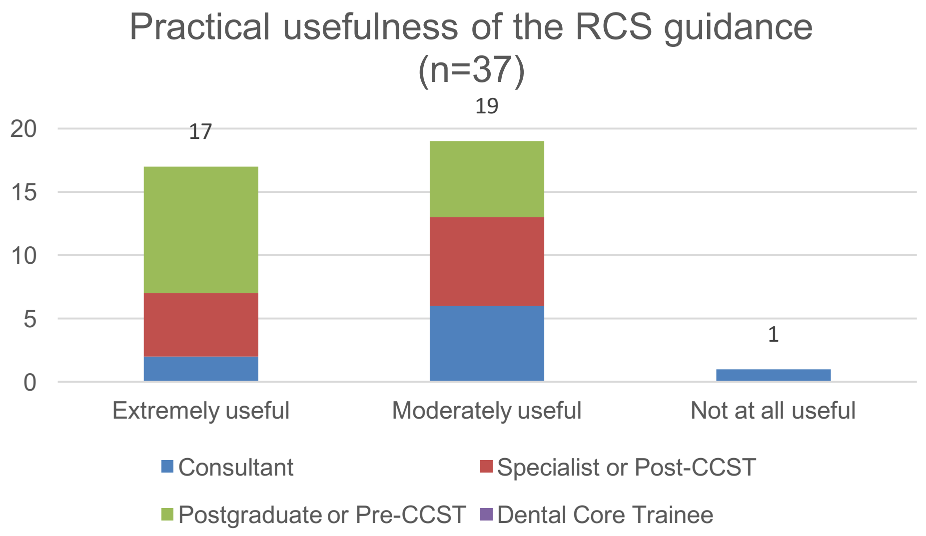


Figure 5-40: distribution of clinicians' view about usefulness of the guidance (n=37)

When asked about how robust they thought the evidence behind the guidance was, over half thought it was not robust (n=20; 54.0%). This was followed by 9 (24.3%) clinicians stating it is moderately robust, 6 (16.2%) unsure, and 2 (5.4%) stating it is extremely robust. The breakdown of clinicians is shown in Figure 5-41.

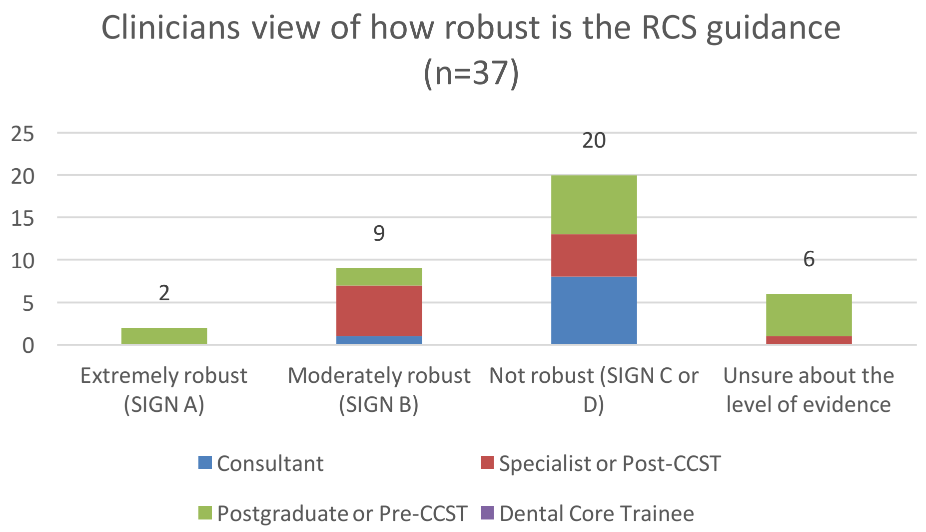


Figure 5-41: Distribution of clinicians' view of the robustness of the evidence behind the guidance (n=37)

5.16.5 Clinicians' attitudes towards the guidance

An open-ended question was used to ask the clinicians (n=37) about their views and opinions of the guidance. Their responses were categorised into:

1. Positive view, implying the guidelines were of value
2. Mixed view, with comments about its value and shortcomings
3. Negative view, expressing shortcomings of the guidance

Over half of clinicians (n=20; 54.0%) had a ***positive view,*** implying the guidance was of value. Comments included that the guidelines are informative, comprehensive, easy to understand, and helpful for treatment planning. There were also a lot of mentions of it being a guideline rather than a set of rules. One clinician commented:

> *"It is a good summary of the evidence around this subject, however it is a guideline only, not mandatory. Therefore, I would also use my clinical judgement to influence my decision as well."*

A few clinicians (n= 7; 18.9%) had a ***mixed view***, stating that the guidance is helpful for the general dentist, but does not always apply to more complex cases. Others found the guidance useful, but believed it would be more practical to have an appendix with relevant clinical scenarios accompanied by their ideal treatment plans and possible treatment outcomes. One clinician's mixed view mentioned the evidence behind the guidance:

> *"Generally it is a good guide but the strength of the evidence is weak, and so perhaps this means that the guidance carries less weight."*

About a quarter of clinicians (n=9; 24.3%) expressed a ***negative view*** of the guidance and expressed its limitations and shortcomings. Comments included that the guidance is hard to follow, confusing with a lot of grey areas and no clear indication of when to balance and compensate sound FPM. One clinician believed that it is very wordy and suggested that a single page summary table for all clinical scenarios would be beneficial. Others believed that there is a lot of emphasis on getting an orthodontic opinion, and not much emphasis on a paediatric dentist's opinion; such as the comment below:

> *"I do think there is a lot of emphasis in the guideline about the need to seek an orthodontic opinion in many situations, with little mention of the overwhelming value of seeking a Paediatric*

Dentistry opinion, as orthodontic considerations are just one component which should be taken into account in the overall decision making process."

5.17 Reproducibility of measurements from this study (intra-examiner agreement)

In order to assess intra-rater reliability of the primary investigator [HB], 25% of the study participants (n=26) were randomly selected using www.random.org; and measurements were repeated at a separate occasion, 3-4 weeks later. With regards to measurements involving orthodontic features, records of the study participants were assessed by the primary investigator [HB], and later confirmed by an experienced orthodontist [JS]. To ensure reliability, records of the 26 randomly-selected study participates were re-measured 3-4 weeks later by the primary investigator [HB], and confirmed again by the experienced orthodontist [JS].

5.17.1 Continuous numerical data

For measurements involving continuous numerical variables, interclass correlation coefficient (ICC) was used to measure agreement. ICC is measured on a scale of 0 to 1, where 1 represents perfect reliability and 0 indicates no reliability; and is usually reported with a 95% confidence interval (CI).

A high degree or reliability/agreement was found in the following measurements involving continuous numerical data, tested using ICC; all of which had narrow 95% confidence intervals and were statistically significant at $p < .0005$.

- *Dental age:* ICC = 0.983, with 95% CI (.962, 0.992)
- *Disease severity by number of FPM affected:* ICC = 0.957, with 95% CI (.957, 0.908).
- *Number of incisors with enamel defect:* ICC = 0.989, with 95% CI (.976, 0.995).
- *DMFT (permanent teeth):* ICC = 0.997, with 95% CI (.993, 0.999).
- *dmft (primary teeth):* ICC = 0.995, with 95% CI (.988, 0.998).

5.17.2 Categorical data

For measurements involving categorical variables, Cohen's Kappa (κ) was used to test agreement. The value of Cohen's κ with corresponding strength of agreement are shown below:

Cohen's Kappa (κ)	**Agreement**
< .20	Poor
. 21-.40	Fair
.41-.60	Moderate
.61-.80	Good
.81-1.00	Very good

The majority of measurements involving categorical data had **very good agreement** (Cohen's κ .81-1.00), as listed below; all of which were statistically significant at $p < .0005$.

- *Diagnosis* (Caries, MIH, AI): Cohen's κ = 1.00.
- *Lower SPM development stage* (stage D, stage E, stage F, stage G, stage H): Cohen's κ = .829.
- *Incisors enamel defect* (yes, no): Cohen's κ = 1.00.
- *HPM* (yes, no): Cohen's κ = 1.00.
- *FPM disease severity* (mild, moderate, severe, sound, previously extracted):
    - UR6: Cohen's κ = .902: UL6: Cohen's κ = .900; LL6: Cohen's κ = 1.000; LR6: Cohen's κ = 1.000.
- *FPM enamel defect type* (AT, DO, PEB, No defect):
    - UR6: Cohen's κ = .831; UL6: Cohen's κ = .946; LL6: Cohen's κ = .938; LR6: Cohen's κ = 1.000.
- *Dental development stage* (early mixed, intermediate mixed, adolescent): Cohen's κ = 1.000.
- *Molar relationship* (class I, ½ unit class II, class II, class III):
    - Right: Cohen's κ .940; Left: Cohen's κ = 1.000.
- *Incisor relationship* (class I, class II div 1, class II div 2, class III): Cohen's κ = .942.
- *Overjet* (mild, moderate, severe, no increased overjet, not applicable): Cohen's κ = 1.000.
- *Reverse overjet* (mild, moderate, severe, no reverse overjet, not applicable): Cohen's κ = 1.000.
- *Overbite* (decreased, average, increased, not applicable): Cohen's κ = .888.
- *Openbite* (mild, moderate, severe, no openbite):

  - Anterior openbite: Cohen's κ = 1.000.
  - Posterior openbite: Cohen's κ = .942.
- *Anterior crossbite* (single teeth, multiple teeth, involving primary teeth only, no crossbite): Cohen's κ = .893.
- *Posterior crossbite* (unilateral, bilateral, involving primary teeth only, no crossbite): Cohen's κ = 1.000.
- *Crowding* (mild, moderate, severe, no crowding, predicted crowding, no predicted crowding) Cohen's κ = .910.
- *IOTN's dental health component:* Cohen's κ = .952.
- *IOTN's orthodontic treatment need:* Cohen's κ = 1.000.

The following measurements had **good agreement** (Cohen's κ = .61-.80); both of which were statistically significant at $p < .0005$.

- *Skeletal pattern* (class I, class II, class III): Cohen's κ = .782.
- *Centreline* (coincident, ¼ to ½ width of lower incisor, > ½ width of lower incisor): Cohen's κ = .675.

Overall, assessments of the records of children in this study (photographs, study models, OPT radiographs, clinical notes) showed good reproducibility and agreement.

6 Discussion

6.1 Children's' FPM diagnosis

This study found good agreement (Cohen's kappa .830) between clinicians' reported diagnosis and diagnosis assessed by the primary investigator using relevant indices (Clarkson & O'Mullane, 1989; Weerheijm et al., 2003); However, there were 7 children misdiagnosed as having dental caries in the FPM, when features determined from the photographic records were consistent with the diagnosis of MIH. This finding was not unusual, as MIH is not always correctly diagnosed by dentists due to its rapid progression with significant enamel loss, and the difficulties with differentiating it from other pathologies of dental structure, including: dental caries, enamel hypoplasia, AI and dental fluorosis (Mast et al., 2013). This was illustrated by a study in Malaysia, which found that 45% of general dentists did not feel confident in diagnosing MIH, and most requested clinical training in MIH diagnosis (Hussein et al., 2014). Another study in the UK also found a lack of confidence in the ability of both paediatric dental trainees and dental practitioners to correctly diagnose MIH (Kalkani et al., 2016).

6.2 Ethnicity and MIH prevalence

The ethnicity of the children in this study was predominantly White (82.9%), and a minority were Asian (6.7%) followed by Mixed (4.8%), Black (3.8%) and other (1.9%). This ethnic group distribution is comparable to that of the general population of England and Wales, as per the 2011 Census: 86% White, 7.5% Asian, 3.3% Black, 2.2% Mixed, and 1 % Other (Office for National Statistics, 2012).

Although this study observed a much greater proportion of White ethnicity with MIH, there was no significant differences found between ethnicity groups and diagnosis. Similarly, a study in Leeds, UK found a higher MIH prevalence rate in White ethnicity, compared to Asian, although no significant difference in MIH prevalence was found between the ethnic groups (Zagdwon et al., 2002). A New Zealand study did not find an association between MIH prevalence and ethnicity either (Mahoney & Morrison, 2011).

Other studies, however, have suggested a role of ethnicity in MIH occurrence. It has been explained that since some ethnic groups live in more deprived areas, and there has had been a link between deprivation and MIH prevalence, then this suggests that MIH prevalence may vary in different ethnic groups (Balmer et al., 2012). A study in Singapore confirmed the link of MIH with ethnicity and found that children of Malay ethnicity had significantly higher proportions of MIH compared to Chinese children; but no significant differences were found with children of Indian ethnicity (Ng et al., 2015).

6.3 Chronological age and dental age

A study in Turkey found that children with MIH had accelerated dental development, compared to controls (Tunc et al., 2013); which was consistent with a study on AI children which found similar findings (Seow, 1995). Although this present study had no controls, and the mean age of MIH children was younger (8.5 years) than Caries children (9.2 years), there were no such findings in this present study, as dental age showed a strong positive correlation with chronological age.

6.4 Socioeconomic status

The online IMD tool used in this study to convert subject's postcode into a deprivation quintile (representing 20% of the population), defined quintile 1 as IMD score of ≤ 8.49 indicating *least* deprived, up to quintile 5 as ≥ 34.18 meaning *most* deprived (NPEU, 2016). It is worth clarifying however, that a previous study has used the same IMD score ranges to categorise deprivation, however, quintiles 1 and 5 were reversed (ie quintile 5 was ≤ 8.49 least deprived, and quintile 1 was ≥ 34.18 most deprived) (Balmer et al., 2012).

The children in this study (n=105) showed a trend of increasing percentages from the least deprived quintile (11.4%) to the most deprived (30.5%); although there was a slight peak at quintile 2 (20.0%).

6.4.1 Socioeconomic status and dental caries

Children from the Caries group lived in statistically significantly more deprived areas (Quintiles 3, 4, and 5) than children in the MIH group, who were evenly distributed in the full range of the deprivation quintiles.

With regards to DMFT and dmft, there was a statistically significant positive linear trend of increasing mean DMFT/dmft of children from the least deprived quintile 1 (1.25/1.42) to the most deprived quintile (3.13/4.31). Both permanent and primary teeth dental caries severity therefore increased with increasing deprivation (low in quintile1 to moderate in quintile 5), as previously illustrated in Figure 5-25. This finding was consistent with a study of children in Scotland, which confirmed that increased deprivation was associated with increased levels of dental caries in primary teeth; and the two most deprived quintiles had greater caries levels (Britton & Welbury, 2010).

6.4.2 Socioeconomic status and MIH prevalence

In terms of MIH prevalence and socioeconomic status, this study had slightly over a quarter of MIH children in the most deprived quintile 5 (26.8%), followed by a quarter in the second least deprived quintile 2 (24.4%), followed by quintile 4 (20.7%), quintile 3 (14.6%), and the least deprived quintile 1 (13.4%). The opposite was found in a previous MIH study in Northern England, which revealed that children living in most deprived areas had the lowest MIH prevalence (Balmer et al., 2012). Interestingly, Balmer et al.'s study (2012) found that MIH prevalence rate steadily increased up to the second least deprived quintile (equivalent to quintile 2 in this study), then slightly dropped in the least deprived quintile (equivalent to quintile 1 in this study); and similarly, this present study also discovered a peak in MIH prevalence in the second least deprived quintile (quintile 2). The reason for this is unclear, however, IMD is a complex measure which incorporates multiple domains and sub-domains of different weighting, which are difficult to isolate.

6.5 Dental anxiety

The set of 8 MCDASf questions used for children in this study showed a high level of internal consistency (Cronbach's alpha 0.816), which was consistent with Howard and Freeman (2007), also confirming its internal reliability (Cronbach's alpha 0.82).

6.5.1 Dental anxiety with age and gender

Child's chronological age had no association with overall MCDASf anxiety scores. Gender, on the other hand, showed a small statistically significant correlation with dental anxiety, where girls (21.2 ± 6.5) had higher mean overall anxiety score than boys (18.6 ± 6.5); although neither gender group's mean score was at the cut-off level for 'anxious' (≥26). Girls were statistically significantly more worried than males in 3 out of the 8 MCDASf items, including 'teeth looked at', 'tooth taken out', and 'having gas and air'. There are inconsistent findings with dental anxiety and gender differences in the literature, as some studies have reported girls had higher dental anxiety than boys (Wong et al., 1998; Raadal et al., 1995), while others reported no differences (Buchanan, 2005; Buchanan & Niven, 2002).

6.5.2 Dental anxiety and diagnosis groups

There was a higher mean overall MCDASf score in MIH children (20.3 ± 6.5) than Caries (18.4 ± 7.1) and AI (18.0 ± 3) children; although the difference was not statistically significant and none of the groups' mean anxiety scores were at the 'anxious' level. This finding was similar to a case-controlled study by Jalevik and Klingberg (2002), who used a parent-reported anxiety scale (CFSS-DS) and found that mean dental anxiety scores in 9 year old children with MIH were higher than controls; and neither group's mean score was associated with dental fear. It is worth pointing out that although a CFSS-DS score of ≥38 is associated with dental anxiety (Porritt et al., 2013; Klingberg, 1994), Jalevik and Klingberg's study (2002) had adjusted this cut-off level to ≥29 (i.e. one standard deviation above the study population mean), because only 1 child from the MIH group presented with ≥38. Nevertheless, the authors indicated that 8 (out of 32) children in the MIH group, compared to 4 (out of 44) children in the control group presented with dental fear/anxiety using their adjusted cut-off level of ≥29. Furthermore, it has been shown that parents-proxy answers related to child's dental anxiety tend to be over-estimated, especially in children with behaviour management problems (Gustafsson et al., 2010).

The 9-year old children from Jalevik and Klingberg's study (2002) were followed-up in a subsequent study, which found that MIH children at 18 years of age had similar dental anxiety levels as controls; which they had expected with increasing age, although behaviour management problems were still more common than in controls (Jälevik & Klingberg, 2012).

In this current study, MIH children were statistically significantly more worried than Caries group children in 1 out of the 8 MCDASf items ('having a filling'). This was not surprising, since it has been reported that by the age of 9, children with MIH had as much as 10 times more frequent treatment on FPM than children without MIH; and many of the treatments had been performed without LA (Jälevik & Klingberg, 2002). MIH children being more worried about having fillings could also be attributable to their symptoms of dentine hypersensitivity from normally innocuous stimuli, owing to underlying pulpal inflammation even in non-carious hypomineralised molars (Rodd et al., 2007).

6.5.3 Dental anxiety and behaviour

Behaviour rating plays an important role in dentistry, and the most commonly used scale is the Frankl (1962) behaviour rating scale (Klingberg, 2008). This present study found no difference in children's Frankl behaviour ratings between MIH-group and Caries-group children. However, previous studies suggested that behaviour management problems were significantly more common in MIH children; although there was no significant relationship found between child behaviour and dental anxiety (Jälevik & Klingberg, 2012). Other previous studies likewise did not find an association between child's behaviour and dental anxiety (Klingberg et al., 1999, 1995).

On the contrary, this current study found a statistically significant association between children's Frankl behaviour ratings and presence of dental anxiety (total MCDASf ≥ 26); where 86.5% of children with definitely positive behaviour (++) were not dentally anxious, and 100.0% of children with negative behaviour (-) were dentally anxious, p=.002. Frankl behaviour rating represents the level of cooperation the child has with dental treatment, whereas dental anxiety represents the state the child is in or the level of apprehension the child has towards dental treatment (Klingberg, 2008). Although dental behaviour and dental anxiety are different entities, this study's findings suggest that children with a more positive Frankl behaviour (++) are less likely to be dentally anxious, whereas children with a negative Frankl behaviour rating are more likely to be dentally anxious.

It is worth mentioning, however, that there was an uneven distribution of children within the Frankl behaviour score categories, as there were no children with definitely negative behaviour (- -), only 3 with negative (-), 28 with positive (+), and as much as 74 with definitely positive (++) behaviour. Moreover, Frankl behaviour was assessed in a dental setting involving dental examination-only and no operative treatment, which may have contributed the large proportion of definitely positive (++) Frankl scores.

6.5.4 Dental anxiety of children who did not have study models

There were 6 children that did not have impressions for study models, 2 of which were for reasons of time constraint or inconvenience. The remaining 4 children had refused impressions due to being anxious; where one child had a lower impression attempted, but became upset and cried. This was reflected on their overall MCDASf scores as 3 of the 4 children who refused due to being anxious had MCDASf score ≥ 26, confirming dental anxiety. Both children that did not have impressions due to inconvenience had lower overall scores, indicating they were not dentally anxious. This finding helps verify MCDASf as a tool to measure dental anxiety.

6.6 Oral health related QoL

Children with compromised FPM affected with MIH, Caries, or other conditions may carry a high burden of disease; and so it was valuable to assess impact on QoL including oral health, functional, and social-emotional wellbeing. A child-reported questionnaire (COHIP-SF19) was employed to assess oral health related QoL of children in this study, as a quantitative method. A low overall score indicated positive oral health related QoL and a lower impact. The 19 items in the questionnaire showed a high level of internal consistency (Cronbach's alpha 0.871), which agreed with previous findings (Broder et al., 2012).

6.6.1 QoL with age and gender

Children's chronological age had no association with overall QoL score, neither did their gender. There was also no differences in each of the 19 items between the genders. Marshman and co-authors (2009) likewise found no links between age and gender with impact on QoL. A study of school children with dental fluorosis in Tanzania also found no association of with age, however they did find a statistically significant gender difference; where females reported more dissatisfaction with dental appearance than males (Åstrøm & Mashoto, 2002). Similarly, a study of psychosocial impact of enamel defects among 16 year olds in Malaysia found a gender difference, with females more dissatisfied than males (Sujak et al., 2004).

6.6.2 QoL and diagnosis groups

Mean QoL scores were higher in Caries children (29.0 ± 11.8) than MIH children (21.6 ±12), and lowest in AI children (16.3 ± 4.6). However, statistical significance was only found between MIH and Caries groups where the latter group had significantly higher mean scores, indicating poorer QoL levels.

Investigation of the differences in scores of each of the COHIP-SF19 items between MIH and Caries children revealed significant differences in 4 out of the 19 items which fall under the functional wellbeing and social-emotional wellbeing subscales with none under the oral health wellbeing subscale. Caries group children had significantly higher scores in the functional subscale items 'trouble sleeping' and 'difficulty cleaning teeth', and the social-emotional subscale item 'not wanted to speak out loud in class'. MIH children however, had higher scores for 'been confident', indicating Caries children expressed significantly less self-confidence. These results are similar to a study in Western Australia, where school children presenting with high caries experience had presented with poorer oral health related QoL than children with enamel defects on their FPM. Furthermore, no association was found between oral health related QoL and presence of enamel defects on FPM (Arrow, 2013). Another study in Australia also found that children with increased caries experience had a negative impact, while children with mild enamel defect on anterior teeth (fluorosis) had a positive impact on child and parental reported oral health related QoL. It has been flagged, however, that exposure to fluorides reduces caries experience, hence reducing negative impacts on QoL (Do & Spencer, 2007). Conversely, presence of enamel defects (severe dental fluorosis) was found to negatively impact functional, social and psychosocial wellbeing (ie QoL) of schoolchildren in Tanzania (Åstrøm & Mashoto, 2002).

6.6.3 QoL and teasing/ bullying

It is not uncommon for school age children to be teased and bullied. Previous studies show that 26% of 8-9 year old children reported being bullied 'sometimes or more often' and 10% 'more than once a week'; although the incidence of bullying was shown to decrease with age (Boulton & Underwood, 1992).

In this present study, less than a third (27.6%) of children reported they had been teased or bullied 'sometimes' (15.2%), 'fairly often' (5.7%), and 'almost all the time' (6.7%); nevertheless, the question was not specific to dental reasons. Rodd et al. (2011), however, reported that 56% of children aged 7-16 with enamel defects have received unkind remarks from peers about their teeth. This psychological bearing is thought to impact young individuals in many ways, including seeking cosmetic dental treatment, where an empathetic approach by the clinician is invaluable (Marshman et al., 2009).

6.7 Enamel defects

This study investigated presence of enamel defects on FPM, permanent incisors, and primary molars.

6.7.1 FPM enamel defects

Children in this study had each of their FPM assessed for presence of DO, PEB, AT restoration/cavity pattern, diffuse, hypoplastic, combination defects, or whether it was previously extracted. All children in the MIH group had 1 or more FPM with an enamel defect type, as expected by definition (Weerheijm et al., 2003). None of the children in the Caries group had an FPM enamel defect; although 1 child had a previously extracted FPM. Children in the AI group had each of their FPM affected with the same enamel defect (1 diffuse, 1 hypoplastic and 1 combination hypoplastic/diffuse), which was also expected due to the nature of the condition.

6.7.1.1 FPM defects in MIH children

In this study, the mean number of affected FPM per child in the MIH group was 3.1. This was comparable to the mean of 3.4 in Lygidakis et al. (2008) and 3.16 in Muratbegovik et al.'s (2007) studies; yet higher than 2.4 from Jalevik et al.'s (2001a) and Chawla et al.'s (2008)'s studies; and much higher than 1.87 in Balmer's (2013), and 1.9 in Zawaideh's (2011) studies. The higher number of affected FPM in children in this study, could be attributed to the study design; in which all children in this study were referred for specialist management, perhaps representing the proportion of the population with more severe disease.

This current study found that over two-fifths (43.9%) of MIH children had 4 FPM affected, followed by a third (29.2%) with 3 FPM affected, a fifth (21.9%) 2 FPM, and a small minority (4.8%) with 1 FPM affected. This was comparable to Lygidakis et al.'s (2008) study which found as much as 68% of children with MIH had 4 FPM affected. Interestingly, these findings conflicted with other studies, which found the opposite, where the majority of MIH children had 1 FPM affected (Balmer, 2013; Ghanim et al., 2011a; Zawaideh et al., 2011; Da Costa-Silva et al., 2010; Arrow, 2008; Preusser et al., 2007). Although the majority of MIH children in Jalevik et al.'s (2001a) study had 1 FPM affected, a quarter of children (24.2%) had 4 FPM affected.

This present study found no significant association between number of FPM affected and disease severity. By contrast, other studies have found that with increasing number of affected FPM, MIH defects were more severe (Zawaideh et al., 2011; Jasulaityte et al., 2007; Jälevik et al., 2001a; Leppaniemi et al., 2001). The variation in methodology of MIH studies, particularly in MIH judgment and severity scales, could have contributed to this difference.

6.7.1.2 Prevalence of FPM defects in MIH children

Prevalence of the presence of 1 or more FPM enamel defect type in MIH children on a child-level was 85.3% PEB, followed by 65.6% DO, 19.5% AT restoration/cavity pattern. Children in the MIH group had a total of 326 FPM present, and the prevalence of FPM enamel defects on a tooth-level was 78% (n=255 FPM). PEB was the predominant defect in FPM (overall prevalence 45%), followed by DO (25%), AT restoration/cavity pattern (7%), and a minority with unerupted FPM (0.6%).

Most studies, however, found that DO was the most common enamel defect in MIH children (Petrou et al., 2014; Ghanim et al., 2011a; Da Costa-Silva et al., 2010; Arrow, 2008; Jasulaityte et al., 2007). Although Jankovic et al.'s study (2014) reported that DO was the most common MIH defect in affected permanent teeth, their results also show that PEB was most common in FPM, whereas DO was the most common defect in incisors. Moreover, Balmer et al. (2015a) found significantly increased risk for MIH children to have PEB on FPM; although PEB was likely reflected under the mDDE index category 'hypoplastic defect'.

In this study, PEB was assigned not only to teeth showing classical signs of surface enamel loss with irregular borders associated with DO, but also to teeth with extensive coronal breakdown without visible pre-existing DO in MIH children (Weerheijm, 2004; Weerheijm et al., 2003). This may have contributed to increased PEB defects in MIH children in this study, compared to other studies. Furthermore, all children in this study were referred to secondary care for specialist management, and therefore may represent a sample of the population with more severe disease.

There has been great variation in methodology of MIH studies around the world, and therefore results of previous studies were difficult to compare with, in particular, due to differences in MIH judgement and severity scales, as well as how data was presented. Recent studies have proposed MIH scoring methods and suggested ways to standardise upcoming MIH studies to enable more valid comparability (Elfrink et al., 2015; Ghanim et al., 2015; Jälevik, 2010).

6.7.1.3 Distribution of FPM defects in MIH children

This study revealed a similar distribution in FPM enamel defects between the upper and lower arches, as well as right and left sides. Similarly, MIH studies in Australia (Chawla et al., 2008), Hong Kong (Cho et al., 2008), Italy (Calderara et al., 2005), Greece (Kotsanos et al., 2005), Sweden (Jälevik et al., 2001a), and the

Netherlands (Weerheijm et al., 2001) found no difference in distributions of FPM enamel defects between both upper and lower arches nor right and left sides.

However, there are conflicting findings in the literature, as some studies found upper arch FPM were significantly more affected (Arrow, 2008; Lygidakis et al., 2008; Preusser et al., 2007; Leppaniemi et al., 2001); whereas other studies found lower arch FPM significantly more affected (Zawaideh et al., 2011; Jasulaityte et al., 2007). Although reasons for increased prevalence in either upper or lower arches are unknown, Leppaniemi et al. (2001) suggested that it could be due to upper FPM mineralisation taking place in a 'more critical time period'; as mineralisation occurs earlier than in lower FPM. A study on Greek children interestingly found a significant difference in affected FPM between right and left sides, and that the UR6 was significantly more frequently affected (Lygidakis et al., 2008).

6.7.2 Incisor enamel defects

Permanent incisors were also assessed for enamel defects. Prevalence on a child-level for Caries group was 20.0%, where the majority of defects were diffuse (on upper centrals) and 1 was hypoplastic (upper lateral). These findings were comparable UK children, as the 2013 Child Dental Health Survey reported over a quarter (28%) of 12 year olds had 1 or more permanent teeth with an enamel defect, of which DO and diffuse were the most common defect types, and the upper centrals most likely affected (Pitts et al., 2015). Children in the AI group had a 100% prevalence, as the condition presents as generalised enamel defects on both dentitions.

6.7.2.1 Prevalence of incisor defects in MIH children

This study found a high prevalence of children with MIH having 1 more permanent incisor with an enamel defect (81.7%); which was not too far off from prevalence of 71.6% in Greek children (Lygidakis et al., 2008). Although a prevalence of up to 92% incisor involvement has been reported in MIH children (Muratbegovic et al., 2007), most studies reported much lower prevalence: 61% in Australian (Chawla et al., 2008) and Danish (Wogelius et al., 2008) children, 51% in Brazilian children (Jeremias et al., 2013), 46.7% in children in England (Balmer, 2013), and as low as 23% in German children (Dietrich et al., 2003).

This study found that children with MIH had a mean of 1.79 incisors with a demarcated enamel defect (or 1.80 if we include diffuse defects). Although this finding was close to a mean of 2.2 reported by Lygidakis (2008), it was much higher than Balmer (2013) and Zaweideh (2011), whom reported a mean of 0.9 and 0.6 incisors affected in MIH children, respectively.

The higher prevalence of permanent incisor defects of MIH children in this study compared to previous studies could be attributed to methodology, where all children in this study were referred for specialist care, and therefore may represent the more severely affected children with MIH. Furthermore, the variation in methods of enamel defect judgment in MIH studies could have played a role.

With regards to defect type, almost all were DO, which were predominantly DO white/cream (81.0%) followed by DO yellow/brown (15.5%). Diffuse defects were seen on only 3.3% on incisors, and no PEB was present on any of the permanent incisors. Enamel defects on incisors were milder and not generally associated with enamel loss than those found on FPM. The literature has attributed this to the absence of masticatory forces on incisors, compared to molars (Jälevik & Norén, 2000). Furthermore, there has been some evidence of abrasion secondary to tooth brushing on demineralised enamel (Wiegand et al., 2007), although the demineralisation was acid-induced and not involved by MIH. With regards to defect type, a longitudinal study had demonstrated that darker enamel opacities had a higher risk of PEB over time (Da Costa-Silva et al., 2011).

6.7.2.2 Distribution of incisor defects in MIH children

Regarding distribution of enamel defects on permanent incisors in MIH children, over half (55%) involved upper centrals, followed by a fifth (20.2%) lower laterals, around a sixth (17.5%) lower centrals, and a small minority (6.7%) of upper laterals (i.e. upper centrals >lower laterals > lower centrals > upper laterals). In this study, the low number of affected upper laterals could be attributable to the substantial proportion unerupted (n=40) or developmentally missing (n=9) upper laterals.

Many studies also agree that incisors in the upper arch were more commonly involved with MIH defects than the lower arch, namely the upper central incisors (Balmer et al., 2015b; Zawaideh et al., 2011; Cho et al., 2008; Lygidakis et al., 2008; Preusser et al., 2007). As for the lateral incisors, this present study found that lowers were more frequently affected than the uppers, which is in agreement with some studies (Zawaideh et al., 2011; Jasulaityte et al., 2007), yet contradicted most (Balmer et al., 2015b; Lygidakis et al., 2008; Wogelius et al., 2008; Preusser et al., 2007). Interestingly, Jankovic et al. (2014) reported the most frequent affected incisors were the lower right centrals; although for all incisors, defects were equally present in both arches.

6.7.2.3 Incisor defects and primary predecessors

Presence of caries or trauma in primary incisor have been linked to enamel defects on permanent incisors. A cohort study in Chinese children found that presence and size of untreated caries in the primary incisors by age of 4 years was significantly associated with the development of DO and hypoplasia in the permanent incisors (caries free: 2.9% DO and 0.7% hypoplasia; large caries 21.6% DO and 9.8% hypoplasia) (Lo et al., 2003). Trauma to primary teeth also caused disturbances in permanent successors, where DO was the most common defect (Skaare et al., 2013); however, only 10% of enamel disturbances of permanent incisors were attributed to trauma in the primary predecessor (Andreasen & Ravn, 1973).

6.7.3 Relationship between number of affected FPM and presence of incisor defect

This present study revealed that an increase in the number of affected FPM was associated with an increase in the number of incisors with enamel defects (Spearman's rank-order correlation rs= .302, p=.006); which was very similar to Blamer's (2013) findings (rs=.21, p<0.001). Many other studies have found a positive correlation (Ghanim et al., 2011a; Da Costa-Silva et al., 2010; Cho et al., 2008; Preusser et al., 2007); however, Jalevik et al (2001a) also found that increased number of incisors affected was associated with increased in severity of FPM defects. In contrast, Mejare et al. (2005) and Kotsanos et al. (2005) did not find any associations between the number of affected FPM and incisors.

All erupted teeth should be examined for enamel defects in children with MIH, as studies have shown that tips of canines can be affected, as well as second primary molars (Jälevik, 2010; Elfrink et al., 2008).

6.7.4 Hypomineralised primary molars (HPM)

Hypomineralsed primary molars (HPM) which present as MIH-like defects, have alternative nomenclature in the literature including deciduous molar hypominerlisation (DMH) (Elfrink et al., 2012) and hypomineralised second primary molars (HSPM) (Elfrink et al., 2015). Caries secondary to HPM lesions do not fit with normal caries distribution, and can be distinguished by display of atypical caries pattern or restoration, as shown previously in Figure 5-21.

Because primary molars erupt 4 years earlier in life than FPM, HPM can be used as an indicator for MIH; and those with affected primary molars were found to have a 4.4 odds ratio of developing MIH with an increased tendency if the number of HPM goes up (Elfrink et al., 2012). HPM was a common finding in MIH children in this present study; although there was no statistical significant relationship between the number of primary molars and number of FPM affected in MIH children.

6.7.4.1 HPM prevalence

The literature reports prevalence of HPM in the general population ranging from 0 to 21%, with an average of 7% (Elfrink et al., 2015). In this present study prevalence of PMH on a child-level in those with MIH was 31.7%; which was comparable to findings of other studies: 39.6% (Ghanim et al., 2013b), 34.8% (Temilola et al., 2015), 32.7% (Mittal & Sharma, 2015) and 30.4% (Costa-Silva et al., 2013); Although the latter reported no significant association between HPM and MIH. The majority of children with PMH in this present study had 1 primary molar affected (42.4%), and about a quarter had 2 primary molars affected (26.9%). Previous studies also found similar results (Ghanim et al., 2013b; Elfrink et al., 2012).

6.7.4.2 HPM distribution

With regards to distribution, this study found the upper E's most commonly affected (61.5%), followed by the lower E's (34.6%). Other studies similarly reported that upper primary molars were more commonly affected than lowers (Negre-Barber et al., 2016; Ghanim et al., 2013b; Lunardelli & Peres, 2005). In contrast, Mittal and Sharma (2015) observed more HPM in the lower arch compared to the lower.

6.7.4.3 HPM and severity of MIH

With regards to MIH severity, it was interesting that this present study found children with mild MIH had significantly increased frequency of HPM occurrence, and children with severe MIH had significantly less HPM ($p < .0005$). Although this study did not record severity of HPM, it was also interesting that studies by Elfrink et al. (2012) as well as Mittal and Sharma (2015) both found higher HPM odds ratios of children with mild HPM defects (opacities) compared to severe HPM (post eruptive enamel loss). This has been attributed to the onset and period of influence of the disturbance, regardless of the aetiology. Mild defects on primary molars occur during later stages of its development (mineralisation or maturation phase), which overlap with the mineralisation of FPM, when ameloblasts are more active (Mittal & Sharma, 2015; Fagrell et al., 2013; Elfrink et al., 2012). In addition, the most common type of HPM defect reported in the literature was opacities (Elfrink et al., 2012; Lunardelli & Peres, 2005; Slayton et al., 2001).

6.7.4.4 HPM and clinical implications

The clinical significance of diagnosing HPM in children is not only because of its close relationship with MIH, but also the dentition is more vulnerable and at increased risk of caries secondary to hypomineralised lesions. It would therefore be wise of the clinician to intervene early in the form of regular topical fluoride application and CPP-ACP products to help promote remineralisation (Crombie & Manton, 2015).

6.8 Hypomineralised FPM and DMFT

It can be difficult to assess DMFT in hypomineralised FPM, as posteruptive enamel breakdown is not true dental caries (Petrou et al., 2014; WHO, 2013). Affected teeth may involve loss of tooth tissue, predisposing it to plaque accumulation and dental caries (Lygidakis et al., 2010; Weerheijm, 2004). Teeth affected by MIH may contribute to increased risk of development of carious lesions, as hypomineralised enamel has a porous surface, allowing bacterial adhesion, invasion and destruction, even in surfaces which visibly appear ‘intact’ (Leppaniemi et al., 2001).

WHO’s (2013) DMFT index aims to not only show caries status and treatment performed due to dental caries, but it also assesses treatment need. Although hypomineralised FPM with posteruptive breakdown into dentine is not true caries, there is an obvious treatment need for those teeth, which justified including them in the DMFT scoring.

DMFT in patients with hypomineralised permanent teeth was assessed in a previous study, where teeth with caries-free posteruptive breakdown was not included in DMFT (Petrou et al., 2014). For this current study, it was not possible to differentiate between carious and caries-free posteruptive breakdown of FPM. In order to have a clear cut methodology, it was decided that any hypominerlised FPM with posteruptive breakdown extended into dentine was scored as ‘Decayed’ in DMFT index. Hypomineralised FPM with posteruptive breakdown into enamel only and no other signs of dental caries in other surfaces, was not scored in DMFT. This was in line with WHO’s (2013) methodology where teeth with white chalky spots, discoloured rough spots, pitted areas of enamel, or teeth showing signs of moderate to severe fluorosis were coded as having a sound crown.

There is a need to accept the fact that when assessing dental caries in children with enamel defects such as MIH, DMFT values may not represent traditional dental caries and may well be overestimated in that cohort, which was demonstrated by a recent systematic review of association between MIH and dental caries (Americano et al., 2017). This review highlighted the need to strengthen controlling strategies of assessing dental caries in patients with hypomineralised teeth. This current study agrees with this recommendation, as it is beneficial for studies to report caries experience on children with enamel defects in a consistent way in order to accurately compare results between different study outcomes.

6.9 Dental caries experience

The Child Dental Health Survey 2013 (Holmes et al., 2015) revealed that there was a reduction in overall dental decay in primary and permanent teeth of children in the UK between 2003 and 2013; although the distribution is uneven and the burden of dental caries as a disease is extensive in those who have it.

Caries experience on a child-level for the full study group for permanent teeth (98.5%) was much higher than the reported levels in England for 8 year olds (33%) and 12 year olds (56%). For primary teeth, children's caries experience (62.2%) was slightly higher than the national reported levels for 5 year olds (49%) and 8 year olds (58%) (Child Dental Health Survey 2013 Holmes et al., 2015). The increase in caries experience compared to reported national levels was an expected finding, as all children in this study were referred for specialist dental management; and therefore represent the sample of the population with more severe dental disease.

In terms of DMFT/dmft, the mean DMFT (permanent teeth) of children in this study (2.33) was much higher than the reported mean for 8 year olds (0.7) and slightly higher than the mean for 12 year olds (1.9). Mean dmft (primary teeth) of children in this study (2.89) was also higher than national mean dmft for 5 year olds (1.8) and 8 year olds (1.9) (Child Dental Health Survey 2013 Holmes et al., 2015)

6.9.1 Dental caries experience between MIH and Caries groups

When assessing caries experience in permanent and primary dentitions between MIH and Caries group children, it was found that mean DMFT/dmft in the Caries group (3.45/5.60) was statistically significantly higher than in the MIH group (2.17/2.44). Children in the Caries group were found to have statistically significantly increased proportions of decayed and missing (due to caries) teeth in both primary and permanent dentitions than children in the MIH group. Although there was a greater frequency of filled teeth in both primary and permanent dentitions in MIH group than Caries group, there was no statistically significant difference found.

Jalevick and Klingberg (2012) found similar DMFT values in both MIH and control groups, indicating that MIH group were not more prone to caries than controls; though MIH affected FPM were very treatment consuming for a low caries population. An epidemiological study of 10-year old children in Germany also found no difference in caries experience between children with and without MIH (Heitmüller et al., 2013). A recent systematic review of seventeen compiled publications from Europe, Asia, and South America, however, found a significant association between MIH and dental caries, where DMF index and caries prevalence was higher in MIH children (Americano et al., 2017). This review also reported that there may be an overestimation of caries values in MIH children due to the common presence of post eruptive breakdown on affected teeth, although presence of enamel breakdown renders the tooth more prone to caries.

It is important to mention prevalence of caries experience in children in this study is subject to selection bias, as all 105 children were referred from their general dentist for secondary dental care and recruited from patient assessment clinics.

6.10 Orthodontic features

Over a half of children in this study had an intermediate mixed dentition (64.6%); and statistically significant differences were found between the diagnosis groups, where there were increased proportions of MIH children in the early mixed dentition (92.5%; n=25), and increased proportions of Caries group children in the adolescent dentition (50.0%; n=4). This could be due to the nature of MIH, where it is evident in early stages when the tooth erupts, whereas dental caries in the permanent dentition is an outcome of an accumulation of events that progress over a period of time (Fejerskov, 1997).

The 2013 Children's Dental Health Survey assessed unmet orthodontic need as the treatment need with a DHC 4 or 5; and found this to be 37% in 12 year olds (Rolland et al., 2016). The orthodontic treatment need in children in this study, however, was much higher than the national levels at 50.5% (40.4% grade 4;

10.1% grade 5); and there were no differences between MIH and Caries groups. The high treatment need could be explained by the overestimation of the severity of ‘crossbite’ (accounted for 47% of grade 4); as the worst category of displacement was assumed as assessment was undertaken on dental cats only (Richmond, 2008). If crossbites were eliminated from the grade 4 treatment need (4c), the unmet orthodontic need of children in this study would be 31.3%, which is similar to the national average. Therefore, the children in this study may not have different orthodontic needs that the general population.

6.10.1 Crossbites and IOTN

There are no clear guidelines in the literature regarding children in the mixed dentition and whether crossbites involving primary teeth are included in the dental health component of IOTN. It was decided to include primary teeth crossbites in the IOTN grading of children in this study, as studies report a link between crossbite in the primary dentition and subsequently the permanent dentition. It has been reported that if a crossbite in the primary dentition remains untreated, the malocclusion tends to worsen; as overtime, remodelling of the teeth and alveolar process occurs, as well as the skeletal structures of the maxilla and the mandible (McNamara, 2002; O’Byrn et al., 1995; Bishara et al., 1994; Clifford, 1971). Furthermore, when assessing crossbite on study models, the worst displacement should be assumed (i.e. 4c) (Richmond, 2008). Crossbite with displacement is therefore an orthodontic need that should be considered when assessing children’s occlusions, regardless of primary or permanent dentition.

There were 19 children in this study who had crossbite (c) as their IOTN deviant trait; including 3 children with crossbite of primary teeth (2 anterior; 1 posterior), and 16 children with crossbite of permanent teeth (5 anterior; 9 posterior; 2 both anterior and posterior). It should be noted however, that 5 out of the 16 children with permanent teeth crossbite as their IOTN deviant trait also had primary teeth crossbite; as exemplified in Figure 6-1 and Figure 6-2.

Figure 6-1: An 8 year old girl with MIH (#069) displaying anterior crossbite of primary teeth (right primary canines) and posterior crossbite of permanent teeth (left FPM)

Figure 6-2: A 6.6 year old boy with MIH (#044) displaying anterior crossbite of primary teeth (primary canines and right laterals) and posterior crossbite of permanent teeth (right FPM)

6.10.2 Differences in occlusion between MIH and Caries children

The parameters of occlusion that revealed statistically significant differences between the diagnosis groups were incisor relationship and dental crowding. There were no significant differences between MIH and Caries children for other orthodontic parameters assessed (skeletal pattern, molar relationship, overjet, reverse overjet, anterior or posterior openbite, anterior or posterior crossbite, overbite, centreline deviation).

Caries group children were found to have significantly increased proportions of Class I incisor relationships (52.6%; n=10) than MIH children (22.0%; n=17). However, no such differences were found in Class II div 1, Class II div 2, or Class III incisor relationships.

In terms of dental crowding, children in the Caries group showed statistically significantly increased proportions of ‘predicted crowding’ in the mixed dentition (36.8%), as well as severe (25.0%; n=1) and moderate (50.0%; n=2) crowding the permanent dentition, compared to MIH children (15.0% predicted crowding in mixed dentition; 0% moderate 0% severe permanent dentition crowding). This agreed with findings in the literature, which suggest that crowding increases caries risk due to food and plaque accumulation in areas of disruption of normal proximal and occlusal contacts (Stahl & Grabowski, 2004; Roder & Arend, 1971). Furthermore, previous extraction of primary teeth due to caries may result in space loss and subsequent crowding. The literature, however, reports conflicting findings around this subject, as other studies found no association between crowding and dental caries (Helm & Petersen, 1989; Addy et al., 1988). The disagreements between studies has been attributed to the multifactorial aetiology of dental caries (Hafez et al., 2012).

The influence of children's orthodontic features on treatment plan, as well as instances where clinicians sought the opinion of an orthodontist are discussed in relevant sections to follow.

6.11 Treatment planning of children with compromised FPM

6.11.1 FPM plan and diagnosis groups

There were significant differences found in agreed treatment plans between children in the MIH and Caries group. In terms of plans involving FPM extractions, Caries children had significantly increased proportions (75.0%; n=15), whereas MIH children had significantly less proportions (40.2%; n=33). In terms of FPM temporisation/review, children in the Caries group had significantly less proportions (0.0%; n=0). Although 100% of children planned for FPM temporisation/review were in the MIH group, which corresponds to a quarter of the group (25.6%; n=21), that increase in proportion was not found statistically significant. The fact that MIH children had more plans for FPM temporisation/review with no operative treatment could be related to the nature of MIH, where disease progress of affected FPM may have a degree of unpredictability and uncertainty, requiring monitoring and reviewing at a later date. Furthermore, Caries group children have FPM caries with no enamel defect, and disease progress would be more predictable, enabling a definite operative plan to be agreed.

With regards to elective extractions, there was a statistically significant difference in proportions of children planned for FPM elective extractions, where 40.0% (n=8) were in the Caries group, compared to only 9.7% (n=8) in the MIH group. Increased FPM elective extractions in the Caries group could be explained because they have no FPM enamel defects, and so opposing FPM may be sound or restorable, hence their extractions are regarded as 'elective'. In MIH children, however, presence of enamel defects with PEB into dentine may not be regarded as restorable, hence their extraction would not be categorised as ‘elective’.

In this study, 15.2% (n=16) of children were planned for 1 or more FPM elective extraction. This majority of elective extractions were upper FPM compensation (n=10 children), a few upper and lower compensating extractions (n=4 children), a couple lower FPM extractions (n=2 children), and no balancing extractions. These findings were slightly similar to a study of FPM extraction in children, which found 17% had compensating extractions, of which the majority were upper FPM; and 8% had balancing extractions (Albadri et al., 2007).

6.11.2 Clinical features influencing FPM plan

This study found that clinical features, including chronological age, dental age, lower SPM development stage, Frankl behaviour rating, and oral hygiene status were significantly associated with certain FPM treatment plans.

6.11.2.1 FPM plan and age

Both chronological and dental age were statistically significantly associated with agreed FPM plans, although dental age had a slightly stronger association. For both chronological age and dental age, the general pattern was that the younger the child the more likely the plan was to temporise the FPM and revisit at a later date (mean chronological age 7.8 years, mean dental age 7.7 years); and the older the child the more definite the agreed plan, which involved extractions and/or restorations (mean chronological age 9.3-9.9, mean dental age 9.1-9.3).

Previous studies of children with poor quality FPM looked into management with extractions of FPM, rather than restorations. The literature reveals that FPM extractions had favourable spontaneous occlusal results when they were carried out between the chronological ages of 8-11.5 for upper arch, and 8-10.5 for lower arch (Eichenberger et al., 2015; Jälevik & Möller, 2007; Thilander & Skagius, 1970). Children in this present study were planned for ‘extractions only’ at mean age 9.3, and ‘extractions and restorations’ at mean age 9.9; which were comparable to previous studies’ findings.

6.11.2.2 FPM plan and lower SPM development stage

A statistically significant association was also found between lower SPM development stage and agreed plan. The association was in a similar pattern to dental and chronological age, where children who’s lower SPM were in earlier stages of development (stage D) had significantly more plans involving FPM temporisation/ review (43.2%; n=16) and significantly less plans involving FPM extraction (21.6%; n=8); whereas children showing more advanced development of lower SPM (stage E) had significantly more plans involving FPM extractions (61.1%; n=22).

This was not a surprising finding, as the RCS guidance (Cobourne et al., 2014, 2009) and its supporting evidence generally recommends FPM extraction when the lower SPM is in stage E (calcification at root bifurcation) for favourable occlusal development and to avoid unfavourable outcomes such as tilting and drifting of adjacent teeth (Williams & Gowans, 2003). However, more recent studies found no relationship between SPM developing stage and occlusal development with space closure, indicating that SPM development did not influence the positioning of lower SPM in either arch (Teo et al., 2016, 2013).

This suggests that the RCS guidance has an important influence on clinicians' decisions regarding FPM planning; and further good-quality studies to add to the available evidence and update guidance would help benefit the management of children with compromised FPM.

6.11.2.3 FPM plan and behaviour

This study showed that children's behaviour rating assessment had a statistically significant impact on FPM treatment planning decisions for 'FPM extractions-only'. Children who displayed negative (-) Frankl behaviour had significantly increased portions (100%; n=3); whereas those whose behaviour was definitely positive (++), had significantly decrease proportions (20.3%; n=15). No other FPM plans were significantly impacted by child's behaviour. This was an expected finding, as children who have behaviour management problems are less likely to cooperate with ideal placement of good-quality restorations, as well as optimum daily maintenance of restorations.

6.11.2.4 FPM plan and oral hygiene

Child's oral hygiene status (or perhaps the clinician's assessment of the child's oral hygiene) had a statistically significant impact on treatment planning decisions of FPM. Children assessed as having poor oral hygiene had significantly more plans involving FPM extraction (74.3%; n=29), whereas those rated with good oral hygiene had significantly less plans involving FPM extraction (20.4%; n=9). This could be attributable to the clinician's assessment of ability to maintain restorations, and hence leaning towards extractions in poor oral hygiene cases to avoid recurrent disease in restored teeth. Additionally, children with symptoms may find it difficult to maintain good oral hygiene, and so poor oral hygiene may be as a result of the severity of the disease rather than a poor dental motivation.

Although there were no studies found which specifically investigated the effect of clinician's rating of their child patient's oral hygiene on an agreed treatment plan, it seems reasonable that children with poorer oral hygiene levels receive more radical treatment (ie. extraction) to help eliminate avoid recurrent oral disease. As with appliance therapy, children with poor oral hygiene and presence of plaque would not be ideal candidates and should not receive such treatment (Cameron & Widmer, 2013).

6.11.3 Orthodontic features influencing FPM plan

This study found dental developing stage, skeletal pattern, and DHC deviant trait crowding were statistically significantly associated with certain FPM treatment plans.

Children in the early mixed dentition had significantly less FPM extractions in their plan. This was an expected finding as EAPD's MIH best practice guidance recommends children in the early mixed dentition to be managed with prevention, adhesive sealants, or glass ionomer restoration (Lygidakis et al., 2010).

FPM extractions were predominant in Class I skeletal children (55.3%), whereas FPM restorations were predominant in Class II skeletal children (56.0%). Children with crowding as their DHC deviant trait has significantly more FPM extractions in their plan (100%). DHC involves setting the worst deviant trait, therefore the children with the most severe crowding had FPM extraction in their treatment plans. These findings agreed with RCS guidance, where the general recommendations are to compensate upper FPM in class I cases; and to restore or temporise and delay extraction of upper FPM in class II cases due to space requirements to correct the relationship (Cobourne et al., 2014). In contrast, a UK previous study did not find any association between incisor relationship or dental crowding with extraction of FPM (Albadri et al., 2007). This difference could be due to the study methodology, as all children in Albadri et al.'s (2007) study required extraction of FPM; whereas this present study all children required management of FPM, regardless of type of treatment needed.

6.11.4 Mode of delivery of treatment plan

Children's treatment plan involved agreeing on a mode of treatment suitable for the child and treatment type, which included GA, LA, IS, or a combination of different treatment modes. Around a fifth of children from the study group did not have treatment mode set, as they were not planned for any active treatment involving operative dental procedures such as restorations and extractions (n=23; 21.9%).

Diagnosis of the child had an association with treatment mode, which was significant in Caries-group children only. Children in the caries group had significantly more plans under GA (60%; n=12), and had significantly less plans involving no operative treatment (0%; n=0). This finding is also comparable with a prospective multicentre study in the UK, which revealed the main reason for extraction of FPM under GA was dental caries with poor prognosis (Albadri et al., 2007).

It seemed reasonable to expect that children treated for treatment under GA would have more numbers of FPM affected, however, there was no significant association found between severity by number of FPM affected and planned treatment mode. By contrast, Albadri et al (2007) found a statistically significant difference between number of FPM extracted and treatment mode; where GA was used in children having 3 and 4 FPM extracted in 90% and 84% of the cases, respectively.

An association was found between oral hygiene and treatment mode, which was significant in poor OH and good OH groups, but not fair OH groups. Children with poor OH had significantly more plans under GA (60.5%; n=23), and significantly less plans involving no operative treatment. It would not be accurate to assume that there is a direct relationship between having poor OH and treatment plans under GA, as GA needs to be justified, and poor OH is clearly not a valid justification. However, there could be an indirect relationship because caries susceptibility is influenced by many factors including oral hygiene habits, where plaque retention is a predictor of high caries risk as well as promotion of caries development (Welbury et al., 2012). Therefore, children with poor OH may have increased dental decay and higher treatment demand, which could explain the increased GA treatment modes in this study.

Child's rated behaviour score was significantly associated with GA and LA modes of treatment only. Children with definitely positive (++) behaviour had significantly more plans under LA (86% of LA plans had ++ behaviour) and significantly less plans under GA (50% of GA plans had ++ behaviour); whereas children with positive (+) or negative (-) behaviour had significantly more plans under GA (57% of + behaviour; 100% of - behaviour). This was not surprising as previous studies found that the common reason for treatment under GA after dental caries was behaviour management problems (Sheller et al., 2003). A study in Helsinki actually found that the main reason for dental treatment under GA was extreme non-cooperation, followed by dental fear (Savanheimo et al., 2012). Similarly, a UK study on FPM extractions showed that more than half the children needing FPM extractions had GA as the mode of anaesthesia used because of lack of cooperation and behavioural problems (Albadri et al., 2007).

In this current study, mode of planned treatment was statistically significantly associated with planning of FPM elective extractions, where 87.5% (n=14) of children planned for FPM elective extraction, had GA as their planned treatment mode. This supports the idea that children having elective extraction are more likely planned for treatment under GA, than other modes of management.

6.12 When did clinicians seek an orthodontic opinion?

In a significant proportion of patients (31.4%), the clinicians of the children in this study sought the opinion of an orthodontist to confirm the treatment plan relating to the FPM. This study investigated the variables associated with seeking an orthodontic opinion.

Although type of planned treatment was not associated with seeking an orthodontic opinion, the disease severity by number of FPM affected had a statistically significant association with seeking an orthodontic opinion. Children who had an opinion sought had significantly less mean FPM affected (1.66) compared to children that did not require an opinion (3.10). This was a predicted finding, as it seems logical that clinicians would want to seek an orthodontic opinion when they consider elective extractions of teeth for orthodontic reasons (ie, less FPM affected); However, when more FPM are affected, the treatment plan would be more clear to the clinician in terms of FPM restorability or prognosis and an orthodontic opinion would probably not be of much value that this at this stage. By contrast, Albadri et al.'s study (2007) found no relationship between number of teeth proposed for extraction and seeking specialist opinion.

In terms of elective extractions, this study found statistically significantly more orthodontic opinions sought in children who were not planned for any FPM elective extractions. The type of elective extraction also showed significant association, as children planned for lower FPM compensating extractions had statistically significantly more orthodontic onions sought. The RCS guidance (Cobourne et al., 2014) may have contributed to this outcome, as it generally recommends considering compensating upper FPM, but not lower FPM, except in very exceptional clinical scenarios, in which case seeking an orthodontic opinion would be valuable.

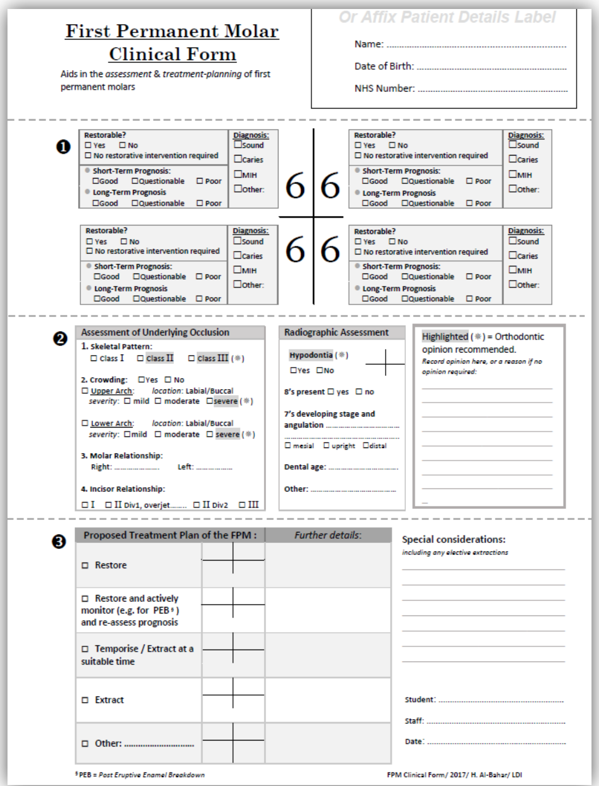
The orthodontic features significantly associated with seeking an orthodontic opinion were orthodontic treatment need and anterior openbite. Orthodontic opinions were significantly more frequently sought in children with moderate need (grade 3). It was surprising to find no significant association with orthodontic opinion and children with great (grade 4) or very great (grade 5) need. This could be attributable to the fact that a large proportion (40%; n=4) of children rated grade 3 had ‘crowding’ as the accompanying deviant trait, whereas children with grade 4 and 5 had ‘crossbite’ (47%) and ‘impacted teeth’ (80%) as the predominant deviant traits, respectively.

Dental crowding is thought to be an important factor to consider when treatment planning FPM loss in order for optimum spontaneous occlusal result; and FPM extraction is a way to orthodontically relieve dental crowding (Gill et al., 2001). The literature reports that FPM extractions would relieve upper labial segment crowding (Thunold, 1970), as well as lower incisor crowding (Richardson, 1979). It was therefore no surprise that clinicians in this present study sought orthodontic opinions in children with orthodontic treatment needs related to dental crowding.

Presence of a severe anterior openbite was also statistically significantly associated with seeking an orthodontic opinion, as 100% (n=2) of children with this malocclusion had an opinion sought. Anterior openbites not related to oral habits are likely to have a significant skeletal component which complicates treatment and requires carful diagnosis and planning (Proffit et al., 2013).

6.12.1 Orthodontic referrals

When clinicians deem an orthodontic opinion necessary, it is imperative to notify the orthodontist about the long term prognosis of each of the FPM, including the need for future FPM restorative care such as crowns into adulthood. A proforma has been developed in a recent audit by the primary investigator [HB] as a practical tool to aid clinicians in the assessment and planning of FPM (Figure 6-3). It prompted clinicians to assess and communicate diagnostic information (clinical, underlying occlusion, radiographic) whenever they felt the need to refer, which improved standards by 57% (Al-Bahar et al., 2016). The use of tools and continued education for paediatric dental clinicians to be mindful of the important aspects of planning for children with poor quality FPM enables more efficient dental management, which benefits affected children and their families with more effective dental visits.


First Permanent Molar Clinical Form

Aids in the *assessment* & *treatment-planning* of first permanent molars

Or Affix Patient Details Label

Name: ....

Date of Birth: ....

NHS Number: ....

❶

Restorable? ☐ Yes ☐ No ☐ No restorative intervention required
Short-Term Prognosis: ☐Good ☐Questionable ☐ Poor
Long-Term Prognosis ☐Good ☐Questionable ☐ Poor
Diagnosis: ☐Sound ☐Caries ☐MIH ☐Other:

Restorable? ☐ Yes ☐ No ☐ No restorative intervention required
Short-Term Prognosis: ☐Good ☐Questionable ☐ Poor
Long-Term Prognosis ☐Good ☐Questionable ☐ Poor
Diagnosis: ☐Sound ☐Caries ☐MIH ☐Other:

6 | 6
6 | 6

Restorable? ☐ Yes ☐ No ☐ No restorative intervention required
Short-Term Prognosis: ☐Good ☐Questionable ☐ Poor
Long-Term Prognosis ☐Good ☐Questionable ☐ Poor
Diagnosis: ☐Sound ☐Caries ☐MIH ☐Other:

Restorable? ☐ Yes ☐ No ☐ No restorative intervention required
Short-Term Prognosis: ☐Good ☐Questionable ☐ Poor
Long-Term Prognosis ☐Good ☐Questionable ☐ Poor
Diagnosis: ☐Sound ☐Caries ☐MIH ☐Other:

❷

Assessment of Underlying Occlusion

1. Skeletal Pattern: ☐ Class I ☐ Class II ☐ Class III (❋)
2. Crowding: ☐Yes ☐ No
☐ Upper Arch: *location:* Labial/Buccal *severity:* ☐ mild ☐ moderate ☐severe (❋)
☐ Lower Arch: *location:* Labial/Buccal *severity:* ☐mild ☐ moderate ☐ severe (❋)
3. Molar Relationship: Right: .... Left: ....
4. Incisor Relationship: ☐ I ☐ II Div1, overjet....... ☐ II Div2 ☐ III

Radiographic Assessment

Hypodontia (❋) ☐Yes ☐No
8's present ☐ yes ☐ no
7's developing stage and angulation ....
☐ mesial ☐ upright ☐distal
Dental age: ....
Other: ....

Highlighted (❋) = Orthodontic opinion recommended.
Record opinion here, or a reason if no opinion required:

❸

Proposed Treatment Plan of the FPM :		*Further details*:
☐ Restore		
☐ Restore and actively monitor (e.g. for PEB§) and re-assess prognosis		
☐ Temporise / Extract at a suitable time		
☐ Extract		
☐ Other:		

Special considerations:
including any elective extractions

Student: ....
Staff: ....
Date: ....

§ PEB = *Post Eruptive Enamel Breakdown*

FPM Clinical Form/ 2017/ H. Al-Bahar/ LDI

Figure 6-3: FPM assessment and planning proforma (Al-Bahar et al., 2016)

6.13 Dental anomalies

Dental anomalies may manifest as variation in tooth number, position, size, shape, eruption, and structure. It has a genetic component, where a single genetic defect may be expressed in different phenotypes such as developmentally absent tooth, microdontia, delayed dental development and ectopic tooth position (Mossey, 1999). Radiographic examination using OPT radiographs is a valuable means to help diagnosis of dental anomalies and disturbances of eruption in paediatric dental patients (Asaumi et al., 2008). Children in this study had a 27.6% (n=29) prevalence of dental anomalies on a child-level (28.0% MIH group; 25.0% Caries group; 33.3% AI group); There were no significant differences in prevalence of anomalies between male and female genders; nor between MIH, Caries, and AI diagnosis groups.

6.13.1 Prevalence of dental anomalies of children in this study compared to the general population

Hypodontia: Children in this study had a 15.2% prevalence of hypodontia, which is more than double the reported 3.5-6.5% prevalence in the general population (AAPD 2015; Polder et al., 2004). Lateral incisor agenesis (5.7% upper; 1.9% lower) had more than triple the prevalence of the general population (1.55-1.78% upper; 0.17-0.25% lower); while second premolar agenesis (2.8% upper; 6.6% lower) had a slightly higher prevalence than the general population of upper second premolar agenesis (1.39-1.61%) and more than double the prevalence of the lower second premolars (2.91-3.22%) (Polder et al., 2004).

Ectopic or impacted teeth: Ectopic Upper FPM had a prevalence of 4.7% in children in this study, which is within the 2-6% reported frequency (Barberia-Leache et al., 2005). Ectopic upper canine prevalence was 5.7%, which is more than triple the reported 1.5% prevalence of the general population (Husain et al., 2016).

The central incisor is the third most commonly impacted tooth, after the third molars and upper canines, with a low incidence of 0.04% (Yaqoob et al., 2016). There was 1 child in this study who presented with an impacted central incisor (1.9%).

Impaction of premolars is relatively rare and accounts for 24% of all tooth impactions with reported incidence ranging from 0.2-0.3% for lower second premolars (Collett, 2000). In this present study, 1 child had bilateral impacted upper premolars (1.9%) and 1 child had bilateral impacted lower premolars (1.9%).

Mesiodens supernumerary: The prevalence of supernumerary in the premaxilla has been reported as 2.6% (Yaqoob et al., 2016), which is similar to the 1.9% prevalence of mesiodens supernumerary in children in this study.

Infraoccluded primary molar: Prevalence of infraoccluded primary molar was 1.9%, which was more than four times less than Kurol's (1981) reported prevalence of 8.9%.

Differences in prevalence of dental anomalies in children in this study compared to reported prevalence from previous studies could be attributed to sample size and the nature of the dental diagnosis of the children. The higher prevalence of dental anomalies (hypodontia, ectopic teeth) of children in this study compared to the general population could be attributable to the fact that the majority of children in this study (78.1%) have MIH, which has a multifactorial aetiology including genetic influence (gene-environmental interactions). It has been suggested that the susceptibility to develop MIH is associated with variations in the genes related to amelogenesis (Jeremias et al., 2016).

6.14 Clinicians' perceptions and planning

Factors influencing clinicians' planning of children with compromised FPM were investigated in two ways; firstly, via clinicians (n=25) responsible for assessing the 105 children in this study; and secondly, via a web-based questionnaire distributed to dental clinicians (n=41) in the Yorkshire and Humber Paediatric Clinical Network group, involved in treating children. Response rates for both were excellent (100%) for clinicians in this study, and very good (74.5%) for the web-based survey respondents (Dillman et al., 2008).

Closed-ended questions incorporating possible clinical and patient factors would be quicker for respondents to select from, and much simpler for the researcher to analyse. This method however, would introduce a great amount of bias, as it would prompt and limit them to the factors listed. To avoid this, open-ended questions were used for clinicians recruited in this study, as well as the clinician respondents of the web-based survey. Open-ended questions allow respondents to express their answers without any influence (Foddy, 1993). A disadvantage of this method was the variation of answers, which was a challenge to analyse, as it required extensive coding.

It is essential to clarify that responses from clinicians recruited in this study were factors which had an influence on their planning specifically for the child study participant they have examined; whereas clinicians' responses from the web-based survey related to general factors they would consider when encountering a child with compromised FPM.

6.14.1 Factors influencing planning of children with compromised FPM

In terms of children in this study, FPM restorability (59.0%) had the greatest influence on clinicians' treatment planning. Around a half were influenced by patient behaviour/cooperation (49.5%), and over a third by presence of symptoms (39.0%). There were no significant differences in influencing factors between MIH, Caries, and AI children, p>.05.

In terms of the general variables that clinicians consider when planning for children with poor quality FPM (web-based survey), the most important factor reported was patient/behaviour cooperation (75.6%); closely followed by FPM restorability (70.7%) and presence/absence of developing teeth (65.8%). Similarly, studies by Hussain et al (2014) and Silva et al (2016) found that child behaviour was a common barrier to treatment of children with MIH-compromised FPM, as reported by clinicians.

Interestingly, the patients' medical histories had a minimal influence (1.9%) on planning of treatment in this study; whereas it was stated as an important factor to consider by around a quarter (24.3%) of clinicians responding to the web-based survey. This may reflect that the children in this study generally had no major health issues; although it was not possible to confirm this. In hindsight, it would have been beneficial to collect medical history information as part of this study's methodology.

Type and mode of treatment (restorations/extractions under LA/GA/IS) had influenced planning decisions in around a fifth of children in this study (21.9%), and was reported as in important factor to consider by nearly a sixth (14.6%) of paediatric clinicians. This may suggest a link between certain anaesthetic modes and treatment types; as GA has been found to be the main mode of treatment for FPM extractions (Albadri et al., 2007).

The literature suggests the most important factors to consider when planning for FPM extractions are restorative state for the FPM, dental age, degree of crowding, occlusal relationship, and presence/condition of other teeth (Gill et al., 2001). Paediatric dental clinicians in this study and respondents from the web-based studt generally agreed with this in terms of FPM restorability and presence/absence of developing teeth; but they also highlighted important patient-related factors that have not been commonly emphasised in the literature: patient behaviour/cooperation and presence of symptoms. Furthermore, children's oral hygiene/motivation as well as overall caries risk influenced clinicians' planning in this study (21.0%; 17.1%) and were considered by clinicians who responded to the web-based survey (21.9%; 24.3%). Gill et al.'s (2001) remaining recommended factors (dental age, occlusion, and crowding) influenced clinician's planning for 15.2- 22.9% of children in this study; and 41.4-63.8% of paediatric clinicians' general considerations.

There are very few published studies exploring factors related to treatment planning of children with compromised FPM and views of the available UK guidance. There are however, several articles on MIH awareness and perception amongst dentists.

MIH which compromises FPM, is a widely recognised condition by dentists in the EAPD (Weerheijm & Mejàre, 2003), Australia and New Zealand (Crombie et al., 2008), UK (Kalkani et al., 2016) ,Iraq (Ghanim et al., 2011b), Iran (Bagheri et al., 2014), Malaysia (Hussein et al., 2014), Saudi Arabia (Silva et al., 2016) and Chile (Gambetta-Tessini et al., 2016). In these studies, which most clinicians agreed it was a clinical problem.

6.14.2 Awareness and opinions surrounding the RCS guidance

Paediatric dental clinicians who responded to the survey (n=41) were asked about their awareness and opinions of the RCS guidance, which offers advice on FPM extractions in children (Cobourne et al., 2014). Nearly half of respondents were postgraduates or pre-CCST, a third were specialists of post-CCST, a quarter were consultants, and only 5% were dental core trainees. The majority (90.2%; n=37) would take into account the RCS guidance when making decisions on FPM planning; over a half (54.0%) reported they would not always follow it, and just below a half (45.9%) would always follow it.

Three-quarters of clinicians who reported they would not always follow the guidance were consultants (40%) and specialists (35%). The survey offered a free-text box to state their reasons when their plans would deviate from the recommended guidance, which included (in the order of most frequently mentioned): orthodontic advice, pain resulting in earlier extraction, abnormalities such as hypodontia, child's cooperation and parent wishes, special needs or complexities in medical history, and when treatment is under GA extractions are more favourable.

It is interesting that almost two-thirds (64.7%) of clinicians who reported that they would always follow the guidance, were postgraduates/ pre-CCST. Although the guideline's advice is not based on strong evidence, it is the best available evidence; and clinicians are advised to use it as a guide and not a set of rules. Many additional factors may influence decision-making process such as child cooperation and access to treatment (Cobourne et al., 2014). This response from postgraduates/pre-CCST could be due to being in the early stages of their training, where they are yet to gain further experience and knowledge in the paediatric dentistry field.

With regard to the usefulness of the guidance, slightly less than a half of clinicians reported it as extremely useful (45.9%), around a half reported it was moderately useful (51.3%), and 1 consultant reported it was not at all useful (2.7%).

With regard to the robustness of evidence behind the guidance, over half stated it was not robust (54.0%), a quarter moderately robust (24.3%), and a sixth unsure (16.2%). A small minority stated that the evidence is extremely robust (5.4%), both of whom were postgraduates/pre-CCST; which may have contributed to the high number of them always following the guidance.

As for the opinions and views towards the guidance, a free-text box was offered for clinicians to state their thoughts. Most clinicians had a positive view implying the guidelines are of value (54%), a quarter had a negative view expressing its shortcomings (24.3%), and less than a fifth had a mixed view commenting about its value as well as shortcomings (18.9%).

Examples of positive views included that it was informative, comprehensive, easy to understand, and helpful for treatment planning. Clinicians with negative views mentioned what they believed were the drawbacks of the guidelines: hard to follow, confusing with many grey areas, no clear indication of when to compensate/balance sound FPM. Several clinicians mentioned that there is a lot of emphasis on seeking an orthodontic opinion, but not much emphasis on seeking paediatric dentist's opinion, which is valuable. Suggestions for improvement of the guidelines included adding an appendix with relevant scenarios and treatment plans with possible outcomes.

6.15 Future research

The majority of published MIH studies have investigated aetiology and prevalence, which is indeed valuable. However, due to the high disease burden and the increased prevalence or recognition of MIH worldwide, it would be advantageous for children with MIH-affected teeth and their families to benefit from more prospective studies on its management. There are many published case reports and retrospective studies on MIH management; but currently, there are no published high-quality evidence-based studies of long-term outcomes of management of children with compromised FPM.

6.15.1 Future research – this study

This is the only study on children with compromised FPM which prospectively investigated dental features, orthodontic features, dental anxiety, and oral-health-related QoL; as well as the effect on clinicians' treatment planning decisions, and factors which clinicians take into account when planning for children with compromised FPM.

As the current study had focused on describing how these children present and how they are planned prior to having dental treatment, a further subsequent study plans to investigate the same children after completing dental treatment, when they are established in the full permanent dentition. This would involve re-inviting the 105 children to take part and collect further records (dental anxiety, oral-health-related QoL, clinical photographs, orthodontic study models) and comparing them to their baseline. It would be interesting to see whether the treatment planned at initial consultation visit differs from treatment received, and whether or not orthodontic treatment was provided. More importantly, the long-term outcomes of the different management provided (restorations, extractions, elective extractions) as well as modes of treatment (LA, GA, IS, Combination) would be evaluated in terms of dental and orthodontic outcomes, as well as patient outcomes in terms of satisfaction with treatment, dental anxiety and oral-health related QoL. OPT radiographs would be valuable for children who had FPM extractions (if indicated clinically, or with ethical approval) to further investigate whether occlusal outcomes were associated with chronological age, dental age, or lower SPM development. Furthermore, it would be advantageous to investigate angle of lower SPM and presence of third molars; as they have been reported as predictors of spontaneous occlusal development by more recent studies (Patel et al., 2017; Teo et al., 2016).

6.15.2 Future research – other studies

This present study as well as previous studies have suggested a link between HPM and MIH. As HPM could be a predictor for MIH, further studies investigating contemporary methods for early management in the primary dentition stage would be beneficial.

Furthermore, It would be interesting for studies to investigate the epigenetic influences of MIH; as they could play a role in assessing possible genetic susceptibility to MIH, which could play an important role in prevention.

7 Conclusions

The findings of this study allowed the following conclusions to be drawn:

Demographics and diagnosis:

1. Although there was good agreement (Cohen's kappa .830) between children's FPM diagnosis reported by the clinician, and diagnosis assessed by the primary investigator, as much as 7 children were misdiagnosed as having caries in FPM, when features determined from the photographic records were consistent with the diagnosis of MIH. This confirms the difficulty in MIH diagnosis.
2. Children from the Caries group lived in statistically significantly more deprived areas than children in the MIH group, who were distributed across the full range of the deprivation quintiles.
3. No significant differences were found in the ethnicities of MIH, Caries, or AI children.

Dental anxiety (MCDASf) and behaviour:

1. Level of dental anxiety was not associated with chronological age.
2. Girls presented with significantly higher mean dental anxiety scores (21.2 ± 6.5) than boys (18.6 ± 6.5); although neither were at the cut-off level for 'anxious' (total MCDASf ≥26).
3. MIH children had higher mean dental anxiety scores (20.3± 6.5) than Caries children (18.4 ± 7.1) and AI (18.0 ± 3) children; although the difference was not statistically significant, and none were at the cut-off level for 'anxious'.
4. MIH children were significantly more worried about 'having a filling' than Caries group children.
5. The majority of children who did not manage dental impressions due to anxiety (3 out of 4), had anxiety scores over the cut-off level for 'anxious' (total MCDASf ≥26).
6. In terms of clinician's assessment of child's behaviour during initial examination, there were no differences in children's Frankl behaviour rating between MIH and Caries children.

7. Frankl behaviour rating was significantly associated with dental anxiety, suggesting that children with a more positive Frankl behaviour score (++) are less likely to be dentally anxious, whereas children with more negative Frankl score (-) are more likely to be anxious.

Oral-health-related QoL (COHIP-SF19):

1. Neither chronological age nor gender were associated with oral-health-related QoL.
2. Caries children had significantly poorer oral-health related QoL scores (29.0 ± 11.8) than MIH children (21.6 ±12).
3. Caries group had significantly poorer QoL than MIH children in 4 out of the 19 items, which fall under the functional wellbeing subscale (‘trouble sleeping’ and ‘difficulty cleaning teeth’) and the social-emotional wellbeing subscale (‘not wanted to speak out loud in class’ and ‘been confident’).

FPM enamel defects – MIH children:

1. MIH children had a mean of 3.1 FPM affected; and 43.9% had 4 FPM affected, followed by 29.2% with 3 FPM affected, 21.9% with 2 FPM affected, and 4.8% with 1 FPM affected.
2. Prevalence of FPM enamel defect in MIH children on a tooth-level was 78% (255/326).
3. PEB was the predominant type of FPM enamel defect in MIH children on a tooth-level (45% overall prevalence), followed by DO (25%, AT restoration/cavity pattern (7%), and unerupted FPM (0.6%).
4. No association was found between number of FPM affected and MIH severity.
5. Severity of FPM enamel defect on a tooth-level was: 43% (n=140) severe, 25% (n=83) mild, 22% (n=70) no enamel defect, and 10% (n=33) mild.
6. There were no differences in the distribution of FPM enamel defects in MIH children between the upper and lower arches, nor the right or left sides.
7. In MIH children, an increase in the number of affected FPM was associated with an increase in the number of incisors with enamel defects (rs= .302, p=.006).

Incisor enamel defects – MIH-group children:

1. Prevalence of incisor enamel defect in MIH group on a child-level was 81.7% (67/82); and on a tooth level was 25.1% (148/588).
2. Children with MIH had a mean of 1.80 incisors affected with enamel defects; of which 81.0% were DO white/cream, followed by 15.5% DO yellow/brown, and 3.3% diffuse.
3. Distribution of incisor enamel defects in MIH children was: 55.0% upper centrals > 20.2% lower laterals > 17.5% lower centrals > 6.7% upper laterals.

Incisor enamel defects- Caries-group children:

1. Prevalence of incisor enamel defect in Caries group was 20% (4/20) on a child-level and 3.9% (6/152) on a tooth-level; where the majority were diffuse defects on upper central incisors, and one 1 child had a hypoplastic defect on an upper lateral.

Hypomineralised primary molars (HPM):

1. Prevalence of HPM in MIH children was 31.7% on a child-level; which strengthens the existing evidence that HPM and MIH are likely to be related conditions and may result from the same aetiological events.
2. The majority of children with HPM had 1 (42.4%), or 2 (26.9%) primary molars affected, and the distribution was: 61.5% upper E's, followed by 34.6% lower E's; and small numbers of upper D's (3.8%).
3. Children with mild MIH had significantly increased frequency of HPM, whereas children with severe MIH had significantly less HPM.
4. There was no significant association between number of FPM affected, and number of HPM.

Dental caries experience:

1. Increased deprivation was associated with increased level of caries in both the permanent and primary dentitions (DMFT/dmft).
2. Children in this study had a mean DMFT/dmft of 2.33/2.89 (low severity).

3. Caries children had significantly higher DMFT/dmft (3.34/5.60; moderate/high severity) than MIH children (2.17/2.44; low severity).
4. Caries children had significantly increased proportions of decayed and missing teeth in primary and permanent dentitions, compared to MIH children.
5. MIH children had higher numbers of filled permanent and primary teeth than Caries children; although there were no significant differences found.

Orthodontic features:

1. There were no differences in the orthodontic treatment need of MIH and Caries children.
2. 50.5% of children in this study had a high orthodontic treatment need (40.4% grade 4; 10.1% grade 5), which is likely overestimated due to assuming the worst displacement when crossbite was present (i.e. all crossbites were recorded as grade 4).
3. Dental crowding: Caries children had significantly more severe crowding the permanent dentition, as well as more ‘predicted crowding’ in the mixed dentition, compared to MIH children.
4. Incisor relationship: Caries children had significantly more Class I incisor relationships than MIH children; however, there were no differences with other incisor relationships.
5. There were no differences between MIH and Caries children in other parameters of occlusion (skeletal pattern, molar relationship, overjet, reverse overjet, anterior or posterior openbite, anterior or posterior crossbite, overbite, centreline deviation).

Dental anomalies:

1. Children in this study had a 27.6% prevalence of dental anomalies on a child-level; and there were no significant differences in prevalence between the genders (male, female) nor the diagnosis groups (MIH, Caries, AI).
2. Prevalence of dental anomaly types (on a child-level):
    - 15.2% hypodontia (6.6% lower premolars > 5.7% upper laterals > 2.8% upper premolars > 1.9% lower laterals)
    - 4.7% ectopic upper FPM

- 5.7% ectopic canines
- 1.9% impacted central incisor
- 24% impacted premolars
- 1.9% mesiodens supernumerary
- 1.9% infraoccluded primary molar

<u>Treatment planning of children with compromised FPM:</u>

1. Caries children had significantly more plans involving FPM extractions (75.0%) than MIH children (40.2%).
2. A quarter (25.6%) of children in the MIH group were planned for FPM temporisation/review, compared to nil (0.0%) Caries children.
3. Elective extractions:
    - 15.2% (n=16) of children in this study were planned for elective extraction of 1 or more FPM; where the majority were upper FPM compensating extractions.
    - Caries children had significantly increased proportions of FPM elective extractions (40.0%), compared to MIH children (9.7%).

<u>Clinical features influencing FPM treatment plan:</u>

1. Both chronological and dental age were significantly associated with FPM treatment plannimg; where the younger the child (7.8 chronological, 7.7 dental) the more likely the plan was to temporise and review FPM at a later date, and the older the child (9.3-9.9 chronological, 9.1-9.3 dental) the more definite the agreed plan (which involved FPM restorations and/or extractions)
2. Lower SPM development stage was significantly associated with FPM planning: children with lower SPM at stage D (early development) had significantly more plans involving FPM temporisation/review(43.2%) and significantly less plans involving FPM extraction (21.6%) ; whereas those in stage E (calcification at bifurcation) had significantly more plans involving FPM extraction (61.1%).
3. Clinician's Frankl behaviour rating of the child was significantly associated with FPM plan: Children rated as negative behaviour (-) had significantly more plans

involving ‘FPM exactions-only’ (100%); whereas children rated as definitely positive (++) had significantly less ‘FPM extractions-only’ (20.3%).

4. Clinician’s assessment of the child’s oral hygiene was significantly associated with FPM plans involving FPM extractions: Children assessed by the clinician as having poor OH had significantly more plans involving FPM extractions (74.3%), whereas those assessed as having good oral hygiene had significantly less (20.4%).
5. Orthodontic features significantly associated with FPM treatment plan: dental developing stage, skeletal pattern, and DHC deviant trait crowding:
    - Children in the early mixed dentition had significantly less plans involving FPM extractions.
    - Children with Class I had significantly increased plans involving FPM extractions (55.3%), and children with Class II had significantly increased plans involving FPM restorations (56.0%).
    - Children with crowding as their IOTN DHC deviant trait had significantly increased plans involving FPM extraction (100%).
    - There were no significant associations between agreed FPM plan and other orthodontic features (orthodontic treatment need, molar relationship, incisor relationship, overjet, reverse overjet, crowding, anterior or posterior openbite, anterior or posterior crossbite, overbite, and centreline).

Clinical features influencing the mode of delivery of treatment (LA, GA, IS):

1. Mode of planned treatment was statistically significantly associated with planning of FPM elective extractions, where 87.5% of children planned for FPM elective extraction, had GA as their planned treatment mode.
2. Caries children had significantly more treatment plans under GA (60%), and significantly less plans involving no operative treatment (0%).
3. Children rated by the clinician as having poor oral hygiene had significantly more plans under GA (60.5%), and significantly less plans involving no operative treatment.
4. Child’s rated behaviour was significantly associated with GA and LA modes of treatment only: Children with definitely positive (++) behaviour had significantly more plans under LA (86% of LA plans had ++ behaviour) and significantly less

plans under GA (50% of GA plans had ++ behaviour); whereas children with positive (+) or negative (-) behaviour had significantly more plans under GA (57% of + behaviour; 100% of - behaviour).

5. There was no association between severity by number of FPM affected and treatment mode (LA, GA, IS).

Orthodontic opinion – in what instances did clinicians seek an orthodontic opinion?

1. 31.4% of the children in this study had an orthodontic opinion sought.
2. Variables significantly associated with seeking an orthodontic opinion were severity by number of FPM affected and type of elective extraction:
   - The less FPM affected, the more likely an orthodontic opinion was sought (mean 1.66), and the more affected FPM, the less likely an opinion was sought (mean 3.10).
   - Lower compensating extractions was significantly associated with seeking an orthodontic opinion.
3. There was no association between type of FPM treatment (FPM extractions, restorations, temporisation/review) and seeking an orthodontic opinion.
4. Orthodontic features significantly associated with seeking an orthodontic opinion: orthodontic treatment need (moderate grade 3), and presence of anterior openbite.

Clinicians' reported factors influencing FPM planning:

1. For the 105 children in this study, the most commonly reported factors which influenced clinician's treatment planning were: FPM restorability (59.0%), followed by patient behaviour/cooperation (49.5%), and presence of symptoms (39.0%); with no significant differences between MIH, Caries, and AI groups.
2. Through a web-based survey, paediatric dental clinicians reported that patient behaviour/cooperation (75.6%), FPM restorability (70.7%), and presence/absence of developing teeth (65.8%) would have the most influence on planning for children with poor quality FPM.

<u>Clinician's perceptions surrounding the RCS guidance on FPM extractions in children:</u>

1. Although the majority of paediatric dental clinicians would take into account the RCS guidance when planning for children with compromised FPM (90.2%), over a half (54.0%) reported they would not always follow it citing concerns about limitations, and less than half (45.9%) reported they would always follow it.
2. Reported reasons for not following the guidance (in the order of most frequently mentioned): orthodontic advice, pain resulting in earlier extraction, abnormalities such as hypodontia, child's cooperation and parent wishes, special needs or complexities in medical history, and when treatment is under GA extractions are more favourable.
3. Most paediatric dental clinicians believed the RCS guidance was useful (45.9% extremely; 51.3% moderately).
4. Over half of paediatric dental clinicians believed the evidence behind the RCS guidance was not robust (54.0%).
5. Most clinicians had a positive view of the RCS guidance, implying they are of value (54%), a quarter had a negative view expressing its shortcomings (24.3%), and less than a fifth had a mixed view commenting about its value as well as shortcomings (18.9%).
    - Positive views included: informative, comprehensive, easy to understand, and helpful for treatment planning.
    - Negative views included: hard to follow, confusing with many grey areas, no clear indication of when to compensate/balance sound FPM.
    - Several clinicians mentioned that there is a lot of emphasis on seeking an orthodontic opinion, but not much emphasis on seeking a paediatric dentist's opinion, which is valuable.

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9 List of Abbreviations

AAPD	American Academy of Pediatric Dentistry
AC	Aesthetic Component (of IOTN)
AI	Amelogenesis Imperfecta
AT	Atypical restoration
BSI	British Standards Institute
BW	Bitewing radiographs
CCST	Certificate of Completion of Speciality Training
CFSS-DS	Children's Fear Survey Schedule – Dental Subscale
COHIP-SF19	Child Oral Health Impact Profile- short form 19
CPP-ACP	Casein Phosphopeptide-Amorphous Calcium Phosphate
DCLG	Department for Communities and Local Government
DHC	Dental Health Component (of IOTN)
DMFT	Decayed Missing Filled Teeth (permanent dentition)
dmft	decayed missing filled teeth (primary dentition)
DO	Demarcated Opacity
EAPD	European Academy of Paediatric Dentistry
E-MIH	Extracted due to MIH
FPM	First permanent molar(s)
GA	General Anaesthesia
HPM	Hypomineralised primary molars
ICON	Index of Complexity and Orthodontic Treatment Need
IMD	Index of Multiple Deprivation
IOTN	Index of Orthodontic Treatment Need
IS	Inhalation Sedation
LA	Local Anaesthesia
LDI	Leeds Dental Institute
LTHT R&I	Leeds Teaching Hospitals NHS Trust Research & Innovation

MCDASf	Modified Child Dental Anxiety Scale – faces version
mDDE index	Modified Developmental Defects of Enamel index
MIH	Molar Incisor Hypomineralisation
NPEU	National Perinatal Epidemiology Unit, University of Oxford
OPT	Orthopantomagram radiograph
PA	Periapical radiograph
PAR	Peer Assessment Rating
PEB	Post-eruptive Enamel Breakdown
QoL	Quality of Life
REC	Research Ethics Committee
RR	Retained roots
UE	Unerupted
WHO	World Health Organization

9.1 Initials of persons mentioned in thesis

HB	Hussa Al-Bahar, Primary investigator
JS	James Spencer, Research supervisor and Consultant Orthodontist
SF	Stephen Fayle, Research supervisor and Consultant in Paediatric Dentistry
MD	Monty Duggal, Academic supervisor and Consultant in Paediatric Dentistry
RB	Richard Balmer, Consultant in Paediatric Dentistry
DP	David Penton, Senior Orthodontic Technician
MF	Michael Flynn, Chief Dental Technician
SH	Susan Hanslip, Dental Therapist
MC	Maria Clarke, Clinical photographer
ZK	Zoe Kakiziba, Clinical photographer
CS	Collin Sullivan, Clinical photographer
EW	Emma Wing, Clinical photographer

10 Appendices

Appendix 1: NHS Research Ethics Committee Yorkshire and The Humber – Bradford Leeds: Approval letter

NHS
Health Research Authority
NRES Committee Yorkshire & The Humber - Bradford Leeds

Room 001
Jarrow Business Centre
Viking Industrial Park
Rolling Mill Road
Jarrow
NE32 3DT

Telephone: 0191 428 3384

16 March 2015

Miss Hussa Al-Bahar
25 Mackenzie House
Chadwick Street
LS10 1PJ

Dear Miss Al-Bahar

Study title:	**Dental and orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or Caries.**
REC reference:	**15/YH/0110**
IRAS project ID:	**157962**

Thank you for your submission of 16th March 2015 responding to the Proportionate Review Sub-Committee's request for changes to the documentation for the above study.

The revised documentation has been reviewed and approved by the sub-committee.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this favourable opinion letter. The expectation is that this information will be published for all studies that receive an ethical opinion but should you wish to provide a substitute contact point, wish to make a request to defer, or require further information, please contact the REC Manager, Gillian Mayer, nrescommittee.yorkandhumber-bradfordleeds@nhs.net. Under very limited circumstances (e.g. for student research which has received an unfavourable opinion), it may be possible to grant an exemption to the publication of the study.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a **favourable** ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations.

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database. This should be before the first participant is recruited but no later than 6 weeks after recruitment of the first participant.

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g. when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non-clinical trials this is not currently mandatory.

If a sponsor wishes to request a deferral for study registration within the required timeframe, they should contact hra.studyregistration@nhs.net. The expectation is that all clinical trials will be registered, however, in exceptional circumstances non registration may be permissible with prior agreement from NRES. Guidance on where to register is provided on the HRA website.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" above).

Approved documents

The documents reviewed and approved by the Committee are:

Document	*Version*	*Date*
Letter from funder [Sponsorship letter]	1	17 September 2014
Letter from sponsor [Letter from Sponsor - Evidence of Insurance]	1	17 September 2014
Other [Child Assent Form]	2	08 January 2015
Other [QoL Questionnaire]	1	24 September 2014
Other [Prof Duggal CV]	1	28 November 2014
Other [Mr Fayle CV]	1	01 November 2014
Other [Mr. Spencer CV]	1	01 October 2014
Other [Response to queries]	H. Al-Bahar	04 March 2015
Other [Clinician Questionnaire]	4	10 March 2015
Participant consent form [Parent]	5	10 March 2015
Participant consent form [Clinician]	1	10 March 2015
Participant information sheet (PIS) [Parent]	5	10 March 2015
Participant information sheet (PIS) [Clinician]	1	10 March 2015
Participant information sheet (PIS) [Child 9-12]	5	10 March 2015
Participant information sheet (PIS) [Child 6-8]	2	10 March 2015
REC Application Form		26 February 2015
Research protocol or project proposal [Project Protocol]	3	10 February 2015
Response to Request for Further Information	H. Al-Bahar	09 March 2015
Summary CV for Chief Investigator (CI) [CV (including research training)]	H. Al-Bahar	04 March 2015
Validated questionnaire [Anxiety Questinnaire MCDAS]	1	24 September 2014

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The HRA website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

Feedback

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website: http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance

We are pleased to welcome researchers and R & D staff at our NRES committee members' training days – see details at http://www.hra.nhs.uk/hra-training/

15/YH/0110	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project.

Yours sincerely
pp

Sarah Prothero

Dr Janet Holt
Chair

Email: nrescommittee.yorkandhumber-bradfordleeds@nhs.net

Enclosures: *"After ethical review – guidance for researchers"*

Copy to: *Ms Ann Gowing, Leeds R&D LTHT*

Appendix 2: Leeds Teaching Hospitals NIHS Trust Research & Innovation: Approval letter

The Leeds Teaching Hospitals NHS
NHS Trust

Irfan Jina

Research & Innovation
Leeds Teaching Hospitals NHS Trust
34 Hyde Terrace
Leeds
LS2 9LN

Tel: 0113 392 0162
Fax: 0113 392 0146

r&d@leedsth.nhs.uk
www.leedsth.nhs.uk

18/03/2015

Miss Hussa Al-Bahar

Postgraduate Student
School of Dentistry
University of Leeds
Clarendon Way
LS2 9LU

Dear Miss Hussa Al-Bahar

Re: NHS Permission at LTHT for: Dental and orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre formanagement of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or Caries.
LTHT R&I Number: DT15/073:
REC: 15/YH/0110

I confirm that *NHS Permission for research* has been granted for this project at The Leeds Teaching Hospitals NHS Trust (LTHT). NHS Permission is granted based on the information provided in the documents listed below. All amendments (including changes to the research team) must be submitted in accordance with guidance in IRAS. Any change to the status of the project must be notified to the R&I Department.

Permission is granted on the understanding that the study is conducted in accordance with the *Research Governance Framework for Health and Social Care*, ICH GCP (if applicable) and NHS Trust policies and procedures available at http://www.leedsth.nhs.uk/research/

This permission is granted only on the understanding that you comply with the requirements of the *Framework* as listed in the attached sheet Conditions of Approval.

If you have any queries about this approval please do not hesitate to contact the R&I Department on telephone 0113 392 0162.

Indemnity Arrangements

The Leeds Teaching Hospitals NHS Trust participates in the NHS risk pooling scheme administered by the NHS Litigation Authority "Clinical Negligence Scheme for NHS Trusts" for: (i) medical professional and/or medical malpractice liability; and (ii) general liability. NHS indemnity for negligent harm is extended to researchers with an employment contract (substantive or honorary) with the Trust. The Trust only accepts liability for research activity that has been managerially approved by the R&I Department.

The Trust therefore accepts liability for the above research project and extends indemnity for negligent harm to cover you as investigator and the researchers listed on the Site Specific

Information form. Should there be any changes to the research team please ensure that you inform the R&I Department and that s/he obtains an appropriate contract, or letter of access, with the Trust if required.

Yours sincerely

Anne Gowing
Research Governance Manager

Approved documents
The documents reviewed and approved are listed as follows:-

Document	*Version*	*Date of document*
NHS R&D Form	3.5	25 February 2015
Directorate Approval	2	26 February 2015
REC Letter confirming favourable opinion		16 March 2015
Letter from sponsor [Letter from Sponsor - Evidence of Insurance]	1	17 September 2014
Other [Child Assent Form]	2	08 January 2015
Other [QoL Questionnaire]	1	24 September 2014
Other [Prof Duggal CV]	1	28 November 2014
Other [Mr Fayle CV]	1	01 November 2014
Other [Mr. Spencer CV]	1	01 October 2014
Other [Clinician Questionnaire]	4	10 March 2015
Participant consent form [Parent]	5	10 March 2015
Participant consent form [Clinician]	1	10 March 2015
Participant information sheet (PIS) [Parent]	5	10 March 2015
Participant information sheet (PIS) [Clinician]	1	10 March 2015
Participant information sheet (PIS) [Child 9-12]	5	10 March 2015
Participant information sheet (PIS) [Child 6-8]	2	10 March 2015
Research protocol or project proposal [Project Protocol]	3	10 February 2015
Summary CV for Chief Investigator (CI) [CV (including research training)]	H. Al-Bahar	04 March 2015
Validated questionnaire [Anxiety Questionnaire MCDAS]	1	24 September 2014

Appendix 3: Publicly accessible online published study summary

http://www.hra.nhs.uk/news/research-summaries/dental-and-orthodontic-features-of-fpm-with-mih-or-caries/

www.hra.nhs.uk/news/research-summaries/dental-and-orthodontic-features-of-fpm-with-mih-or-caries/

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Research Summaries ▸ Dental and Orthodontic Features of FPM with MIH or Caries

Dental and Orthodontic Features of FPM with MIH or Caries

Full title	Dental and orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or Caries.
Research type	Research study
IRAS ID	157962
Contact Name	Hussa Al-Bahar
Contact Email	efy4hab@leeds.ac.uk
Sponsor organisation	
Eudract number	
ISRCTN number	
Clinicaltrials.gov identifier	
Additional reference number fields	
Research summary	A common reason first permanent adult molar teeth (FPM) to be of poor quality is the increasingly recognised incidence of a condition affecting these teeth's development called Molar Incisor Hypomineralisation. Teeth affected by this condition are weaker and easily break with normal everyday chewing, and are at risk of tooth decay and tooth sensitivity. Management of FPMs affected by MIH can be problematic and often requires a multidisciplinary approach. Treatment options may include restoring the affected teeth with a filling, a crown, or extracting the tooth. Evaluating whether to restore or extract an affected FPM relies on many factors. Dentists encounter children with both baby and adult teeth present whom have poor quality FPM and therefore will need to decide whether to extract these FPM or to restore them. It therefore seems appropriate to conduct a study, which investigates children referred to a specialist centre for management of FPM with MIH or other conditions; and to describe their presenting dental (health of teeth) and orthodontic (alignment of teeth) features; as well as associated factors which might affect their management, including their baseline level of anxiety and baseline quality of life (ie prior to any treatment intervention). Reassessment of these variables at a later stage would also be used as a basis for subsequent studies to evaluate outcomes of the various treatment interventions in this study group. The study will also explore the variables which affect clinicians' treatment planning decision on extracting versus restoring the FPM.
REC Name	Yorkshire & The Humber - Bradford Leeds Research Ethics Committee
REC Reference	15/YH/0110
REC Opinion	Further Information Favourable Opinion
Date of REC Opinion	16 March 2015

Appendix 4: Parent information sheet

[10/03/2015, Version 5]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS Trust

University of Leeds School of Dentistry with the Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

Parent Information Sheet

Title of Study

The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or caries.

Your child has been invited to take part the above named study. Information related to the study has been included in this information sheet. Please read this it before deciding and please don't hesitate to ask any additional questions.

1. Why have I been given a leaflet?

Your child's referral letter and/or the dentist who examined your child at the hospital has found that your child fulfils the criteria for the study. This information sheet will help you understand more about this study and will help you decide on whether you want to include your child in this study or not.

2. What is the purpose of this study?

This is a postgraduate student project contributing to a Postgraduate Research Degree.

Some children present with relatively common conditions which affect the quality of their first permanent molars (back adult teeth). These conditions are Molar Incisor Hypomineralisation (MIH) or dental decay, or a combination of both. MIH is a condition affecting the permanent molar teeth and sometimes the permanent front teeth too. The cause of MIH is not yet fully understood. Currently, there is very little published information about how these conditions affect children in terms of dental anxiety (how worried they are about dental treatment), quality of life, and how good the outcome of the various treatments.

This study aims to find out the reasons why dentists decide on certain treatment options and whether the current guidelines dentists follow provide the most beneficial advice. It will also help us provide a better understanding of these conditions, especially what effects they have on children and will help us to improve future dental care of patients presenting with these conditions.

3. Who is doing the study?

The study will be conducted in the Children's Department at Leeds Dental Institute by a postgraduate in Paediatric Dentistry (Hussa Al-Bahar) under the supervision of a consultant in Paediatric Dentistry (Mr. Stephen Fayle) and a consultant in Orthodontics (Mr. James Spencer).

4. Does my child have to take part?

Your child seems to fulfil the criteria of this study, however, further confirmation of whether your child is suitable for this study would be confirmed following your first dental appointment. Participation in this study is entirely voluntary. If you choose for your child not to be involved, that will not be a problem and the planned treatment will still be managed as normal.

5. What will be involved if I take part in this study?

As part of routine care, a consultation appointment will be carried out by relevant dentists, which involves a dental assessment and any necessary x-rays. If you agree for your child to participate in this study, what would be different at this appointment is that the dentist will ask your child a series of short questions related to his or her dental anxiety (how worried they are about dental treatment) and will be asked to fill-out a questionnaire regarding Quality of Life, in which assistance will be available.

As having this dental condition carries a high risk of dental decay, an appointment will be arranged to provide preventive care and support for your child such as: support on tooth-brushing technique, providing fluoride treatment and preventive plastic coatings on teeth (ie fissure sealants). Preventive care is a routine part of children's treatment plan here at the Leeds Dental Institute.

[10/03/2015, Version 5]

If your child joins this study, we would need to collect further information at this prevention appointment, which includes: dental photographs and dental impressions (moulds) of your child's teeth. The moulds are the type routinely taken for children having orthodontic treatment (braces).

Your child will continue their management at the Leeds Dental Institute in the normal way, as planned by the relevant dentists. Being part of the study will not have any impact on how your child is treated. You will be contacted in the future for follow up appointments to collect further information after your child's treatment is complete. The reason for the future follow-up visit is to evaluate your child's treatment in the long term. You are free to not include your child in any future research at any time; and this will not effect your child's dental management in any way.

6. Can I withdraw from the study at any time?

Yes, you can withdraw from this study at any time without giving any reasons. Your child will still receive the necessary treatment and reviews, as planned.

7. Will the information I give be confidential?

All information regarding your child will be kept confidential. Clinical information related to your child will be stored in your child's NHS records, which are only accessible by NHS clinicians. The data collected will be kept secure and confidential using non-identifiable information on password-protected computers and in lockable secure locations. No names or personal information will be published and data will remain anonymous.

8. What will happen to the results of this study?

The results of this study will be discussed with other colleagues in the department, presented at scientific conferences and in scientific journals. Your child's identifiable information will not be used. If you would like to know the results of the study, please let one of the research team know, and we would be happy to inform you of the results after they are obtained.

9. What if I have a problem?

If you have a concern about any aspect of this study, you should ask to speak with the researchers who will do their best to answer your questions. If you remain unhappy and wish to complain formally, you can do this through the National Health Service (NHS) Complaints Procedure. Details can be obtained from the hospital.

In the event that something goes wrong or you are harmed during the research study, there are no special compensation arrangements. If you are harmed and this is due to someone's negligence then you have grounds for legal action for compensation but you may have to pay your legal costs. The normal NHS complaints mechanisms will still be available to you.

10. Who has reviewed this study?

Bradford Leeds Research Ethics Committee

IRAS Project ID: 157962
REC Reference: 15/YH/0110

Thank you for taking the time to read this information sheet.

If you would like more information or have any questions or concerns about this study, or would like to request a summary of the results of the study, please contact any member of the study team:

Miss Hussa Al-Bahar Postgraduate in Paediatric Dentistry Leeds Dental Institute Clarendon Way LS2 9LU Email: efy4hab@leeds.ac.uk Hussa.al-bahar1@nhs.net	Mr. Stephen Fayle Consultant in Paediatric Dentistry Leeds Dental Institute Clarendon Way LS2 9LU Tel. (0113) 343-6137 Email: S.A.Fayle@leeds.ac.uk	Mr. James Spencer Consultant in Orthodontics Leeds Dental Institute Clarendon Way LS2 9LU Email: james.spencer@yh.hee.nhs.uk james.spencer@midyorks.nhs.uk

Appendix 5: Child information sheet (9-12 years)

[10/03/2015, Version 5]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS
NHS Trust
University of Leeds School of Dentistry with the Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

Child Information Sheet (9-12 yrs)

Title of Study

The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or Caries.

Why are we giving you this leaflet?

- Your dentist saw that your teeth has a special condition, and has sent you to us so that we can help decide what treatment you may need.
- This leaflet will help you understand more about this study and will help you decide whether you want to join this study or not.

What is this study?

- Your teeth have a special condition, and we want to know more about it.
- We are asking you to join this study to look at how much treatment we give you here will help your teeth in the future.
- This study will also help us understand your teeth, and other children with similar teeth as you.

If I join this study, what will happen?

- If you decide to join this study, appointments with your dentist will go on as they normally would. This would include a check-up of your teeth, x-rays of your teeth, and your dental treatment.
- If you decide to join this study, we will need to collect extra information about you:

  1. We will ask you to answer 2 sets of questions about how you feel about your teeth
  2. We will also take pictures of your teeth
  3. We will take moulds of your teeth



- When your treatment with your dentist is complete, we will ask you to come back for a check-up visit.
- You will still have treatment the same way whether you decide to join this study or not.

Do I have to join this study?

- You decide whether you are happy to take part in this study.
- You don't have to join this study if you don't want to.
- Even if join this study, you can change your mind at any time and don't have to continue, and that's fine.

Thank you for reading this sheet ☺

Appendix 6: Child information sheet (6-8 years)

[10/03/2015, Version 2]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS
NHS Trust
University of Leeds School of Dentistry with the Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

Child Information Sheet (6- 8 years)

TITLE OF STUDY

The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of first permanent molars with Molar Incisor Hypomineralisation (MIH) or caries.

- **We would really like your help in our project and this letter will explain what it means.**
- **Your dentist saw that your teeth has a problem and has sent you to us so that we can help decide what treatment you may need.**
- **We want to know more about your teeth. If you join this study, we need to collect extra information about you:**

1. **We will ask you to answer 2 sets of questions about how you feel about your teeth**

2. **We will take pictures of your teeth**

3. **We will take moulds of your teeth**

- **This project will also help us understand your teeth and the teeth of other children that have the same teeth problem as you.**
- **When your treatment with us is complete, we may ask you to come back again for check-up visits.**
- **If you join this study, you can change your mind at any time, and you don't have to continue if you don't want to, and that's fine.**
- **If you feel that you do not want to join our project, that is fine and we will still do the planned treatment for your teeth.**

Thank you for reading this sheet ☺

Appendix 7: Clinician information sheet

[10/03/2015, Version 1]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS
NHS Trust
University of Leeds School of Dentistry with the Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

Clinician Participant Information Sheet

Title of Study

The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or caries.

We would like you to take part the above named study but before you decide, please read the following information.

1. Why have I been given a leaflet?

The patient you have assessed fulfils the criteria for this study. This information sheet will help you understand more about this study and will help you decide on whether you wish to be recruited in this study or not.

2. What is the purpose of this study?

This is a postgraduate student project contributing to a Postgraduate Research Degree.

Some child patients present to the dental clinic with relatively common conditions which affect the quality of their first permanent molars (FPM).These conditions include Molar Incisor Hypomineralisation (MIH) or Dental Caries, or a combination of both. MIH is a developmental defect causing hypomineralisation of FPM and is sometimes associated with similarly-affected incisors. Currently, there is very little published data about how these conditions affect children in terms of dental anxiety, quality of life, and how favourable are the long-term outcomes of the various treatments provided for these child patients.

This project is a first part of a long-term study, which aims to describe the dental and orthodontic features of a cohort of patients with poor quality FPM using a combination of dental photographs and study models; as well as describe these patients in terms of anxiety and quality of life using patient-reported questionnaires. This study would also investigate the reasons why dental clinicians, such as yourself, decide on certain treatment options and what variables are important during this decision-making and treatment-planning process.

3. Who is doing the study?

The study will be conducted in the Children's Department at Leeds Dental Institute (LDI) by a postgraduate in Paediatric Dentistry (Hussa Al-Bahar) under the supervision of a consultant in Paediatric Dentistry (Mr. Stephen Fayle) and a consultant in Orthodontics (Mr. James Spencer).

4. Do I have to take part?

The child patient you have assessed fulfils the criteria of this study, and so a questionnaire would be provided for you to answer questions related to the patient you have seen; as well as a general questionnaire about how you make treatment-planning decisions for these types of patients.

Participation in this study is entirely voluntary. If you do not want be involved, in this study that will not be a problem.

5. What will be involved if I take part in this study?

If you take part in this study, you will be asked to complete a questionnaire for each patient that is a participant in this study, which you have seen at the time of the consultation clinic. You will also be asked to complete a separate questionnaire at another time which relates to how you would generally make treatment-planning decisions for patients with these conditions.

The child participant would continue their management at the LDI in the normal way, as planned at the consultation clinic. Being part of the study will not have any impact on how the child participants are treated.

[10/03/2015, Version 1]

Child participants and their parent/guardian have been informed that they may be contacted in the future for follow up appointments for a future subsequent study to evaluate their treatment in the long-term.

6. Can I withdraw from the study at any time?
Yes, you are free to withdraw from this study at any time without giving any reasons.

7. Will the information I give be confidential?
All information you provide in the questionnaires will be kept confidential. The data collected from the questionnaires will be kept secure and confidential using non-identifiable information on password-protected computers and in lockable secure locations. No names or personal information will be published and data will remain anonymous.

8. What will happen to the results of this study?
The results of this study will be discussed with other colleagues in the department, and may be presented at scientific conferences and in scientific journals. Your identifiable information will not be used. If you would like to know the results of the study, please let one of the research team know, and we would be happy to inform you of the results after they are obtained.

9. What if I have a problem?
If you have a concern about any aspect of this study, you should ask to speak with the researchers who will do their best to answer your questions. If you remain unhappy and wish to complain formally, you can do this through the National Health Service (NHS) Complaints Procedure. Details can be obtained from the hospital.

In the event that something goes wrong or you are harmed during the research study, there are no special compensation arrangements. If you are harmed and this is due to someone's negligence then you have grounds for legal action for compensation but you may have to pay your legal costs. The normal NHS complaints mechanisms will still be available to you.

10. Who has reviewed this study?
Bradford Leeds Research Ethics Committee
IRAS Project ID: 157962
REC Reference: 15/YH/0110

Thank you for taking the time to read this information sheet.

If you would like more information or have any questions or concerns about this study, or would like to request a summary of the results of the study, please contact any member of the study team:

Miss Hussa Al-Bahar Postgraduate in Paediatric Dentistry Leeds Dental Institute Clarendon Way LS2 9LU Email: efy4hab@leeds.ac.uk Hussa.al-bahar1@nhs.net	Mr. Stephen Fayle Consultant in Paediatric Dentistry Leeds Dental Institute Clarendon Way LS2 9LU Tel. (0113) 343-6137 Email: S.A.Fayle@leeds.ac.uk	Mr. James Spencer Consultant in Orthodontics Leeds Dental Institute Clarendon Way LS2 9LU Email: james.spencer@yh.hee.nhs.uk james.spencer@midyorks.nhs.uk

Appendix 8: Parent consent form

[10/03/2015, Version 5]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS
NHS Trust
University of Leeds School of Dentistry with the
Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

IRAS Project ID: 157962
REC Reference: 15/YH/0110

Participant Identification Number:

PARENT CONSENT FORM

Title of project: The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of First Permanent Molars with Molar Incisor Hypomineralisation (MIH) or Caries.

Name of Researcher: Hussa Al-Bahar

Please initial box

1. I confirm I have read and understand the information sheet dated: 10/03/2015 (version 5) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my child's participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.
3. I understand that relevant sections of my child's medical notes and data collected during the study, may be looked at by relevant individuals/staff at the Leeds School of Dentistry, from regulatory authorities, or from the NHS Trust, where it is relevant to my taking part in this research. I give permission for these Individuals to have access to my child's records.
4. I agree for data collected from my child would be kept for a future research study.
5. I agree for my child to take part in the above study.

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Name of Patient	Date	Signature
------------------------------	------------------------------	------------------------------
Name of Person taking consent	Date	Signature

When completed: 1 for participant; 1 for researcher site file; 1 (original) to be kept in medical notes

Appendix 9: Child assent form

[08/01/2015, Version 2]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS Trust

University of Leeds School of Dentistry with the Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

IRAS Project ID: 157962
REC Reference: 15/YH/0110

Participant Identification Number: [ ]

CHILD ASSENT FORM for Ages 6-12.

Title of project: The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of Molar Incisor Hypomineralisation (MIH) or first permanent molar extraction.

Name of Researcher: Hussa Al-Bahar

	Please initial box
1. Have you read (or have read to you) about this project?	
2. Has somebody else explained this project to you?	
3. Do you understand what this project is about?	
4. Have you asked all the questions you want?	
5. Do you understand all the answers to your questions?	
6. Do you understand it's OK to stop taking part at any time?	
7. Are you happy to take part?	

If you did not tick the box or you do not want to take part, don't sign your name.

If you want to take part, you can write your name below.

------------------------------	------------------------------	------------------------------
Name of Patient	Date	Signature
------------------------------	------------------------------	------------------------------
Name of Person taking consent	Date	Signature

When completed: 1 for participant; 1 for researcher site file; 1 (original) to be kept in medical notes.

Appendix 10: Clinician consent form

[10/03/2015, Version 1]

UNIVERSITY OF LEEDS

The Leeds Teaching Hospitals NHS
NHS Trust

University of Leeds School of Dentistry with the
Dental Hospital at Leeds.
Clarendon Way, Leeds LS2 9LU
Tel. Switchboard 0113-244 0111
Dental School Fax: 0113-343 6282

IRAS Project ID: 157962
REC Reference: 15/YH/0110

Participant Identification Number: [ ]

Clinician Participant CONSENT FORM

Title of project: The Dental and Orthodontic features, baseline Anxiety and Quality of Life of children referred to a specialist centre for management of first permanent molars with Molar Incisor Hypomineralisation (MIH) or caries.

Name of Researcher: Hussa Al-Bahar

Please initial box:

1. I confirm I have read and understand the information sheet dated: 10/03/2015 (version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. [ ]
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. [ ]
3. I understand that the data collected during the study, may be looked at by relevant members of the research team at the Leeds School of Dentistry. I give permission for these Individuals to have access to the data I provide. [ ]
4. I agree to take part in the above study. [ ]

------------------------------	------------------------------	------------------------------
Name of Clinician Participant	Date	Signature

------------------------------	------------------------------	------------------------------
Name of Person taking consent	Date	Signature

When completed: 1 for participant; 1 for researcher site file; 1 (original) to be kept in research master file.

Appendix 11: Dental Anxiety questionnaire: Modified Child Dental Anxiety Scale – Faces Version (MCDASf)

(Howard & Freeman, 2007)

Dental Anxiety Questionnaire

Instructions:
Please read out the following 8 questions relating to the child's dental anxiety at this LDI consultation visit, and circle as appropriate. This is to be filled out after appropriate consent is taken.

Faces version of the Modified Child Dental Anxiety Scale (MCDAS$_f$)
(Howard and Freeman, 2007)

For the next eight questions I would like you to show me how relaxed or worried you get about the dentist and what happens at the dentist. To show me how relaxed or worried you feel, please use the simple scale below. The scale is like a ruler going from 1 which would show that you are relaxed, to 5 which would show that you are very worried.

1 would mean: relaxed/not worried
2 would mean: very slightly worried
3 would mean: fairly worried
4 would mean: worried a lot
5 would mean: very worried

Please circle the most applicable number to each of the following questions:

How do you feel about …					
… going to the dentist generally?	1	2	3	4	5
… having your teeth looked at?	1	2	3	4	5
… having your teeth scraped and polished?	1	2	3	4	5
… having an injection in the gum?	1	2	3	4	5
… having a filling?	1	2	3	4	5
… having a tooth taken out?	1	2	3	4	5
… being put to sleep to have treatment?	1	2	3	4	5
… having a mixture of 'gas and air' which will help you feel comfortable for treatment but cannot put you to sleep?	1	2	3	4	5

IRAS Project ID: 157962
REC Reference: 15/YH/0110

Appendix 12: Quality of Life Questionnaire: Child Oral Health Impact Profile – Short Form 19 (COHIP SF 19)

(Broder et al., 2012)

Quality of Life Questionnaire (QoL)

Instructions:
Please ask the child patient to independently fill-out this QoL questionnaire (ie. in the waiting room). Please ask parents NOT to contribute their answers. For children under 8, the researcher, clinician, or assistant could read-out the questions to them. Assistance is available for those children who need it.

Child Oral Health Impact Profile- Short Form 19 (COHIP SF 19)
(Broder, Wilson-Genderson, and Sischo, 2012)

- Please read each statement carefully and choose the answer that best describes you in the past 3 months regarding your teeth, mouth, or face.
- We want to know how you really feel.

Domains	Scoring				
Oral Health – Well-Being	4= Almost all the time	3= Fairly often	2= Sometimes	1= Almost never	0= Never
Q1. Had pain in your tooth/teeth?					
Q2. Had discoloured teeth or spots on your teeth?					
Q3. Had crooked teeth or spaces between your teeth?					
Q4. Had bad breath?					
Q5. Had bleeding gums					
Functional Well-Being	4= Almost all the time	3= Fairly often	2= Sometimes	1= Almost never	0= Never
Q1. Had difficulty eating food you would like to eat					
Q2. Had trouble sleeping					
Q3. Had difficulty saying certain words					
Q4. Had difficulty keeping your teeth clean					
Social-Emotional Well-Being	4= Almost all the time	3= Fairly often	2= Sometimes	1= Almost never	0= Never
Q1. Been unhappy or sad					
Q2. Felt worried or anxious					
Q3. Avoided smiling or laughing					
Q4. Felt that you looked different					
Q5. Been worried about what the people think about your teeth, mouth or face					
Q6. Been teased, bullied, or called names by other children					
Q7. Missed school for any reason					
Q8. Not wanted to speak/read out loud in class					
	4= Never	3= Almost never	2= Sometimes	1= Fairly often	0= Almost all the time
Q9. Been confident					
Q10. Felt that you were attractive (good looking)					

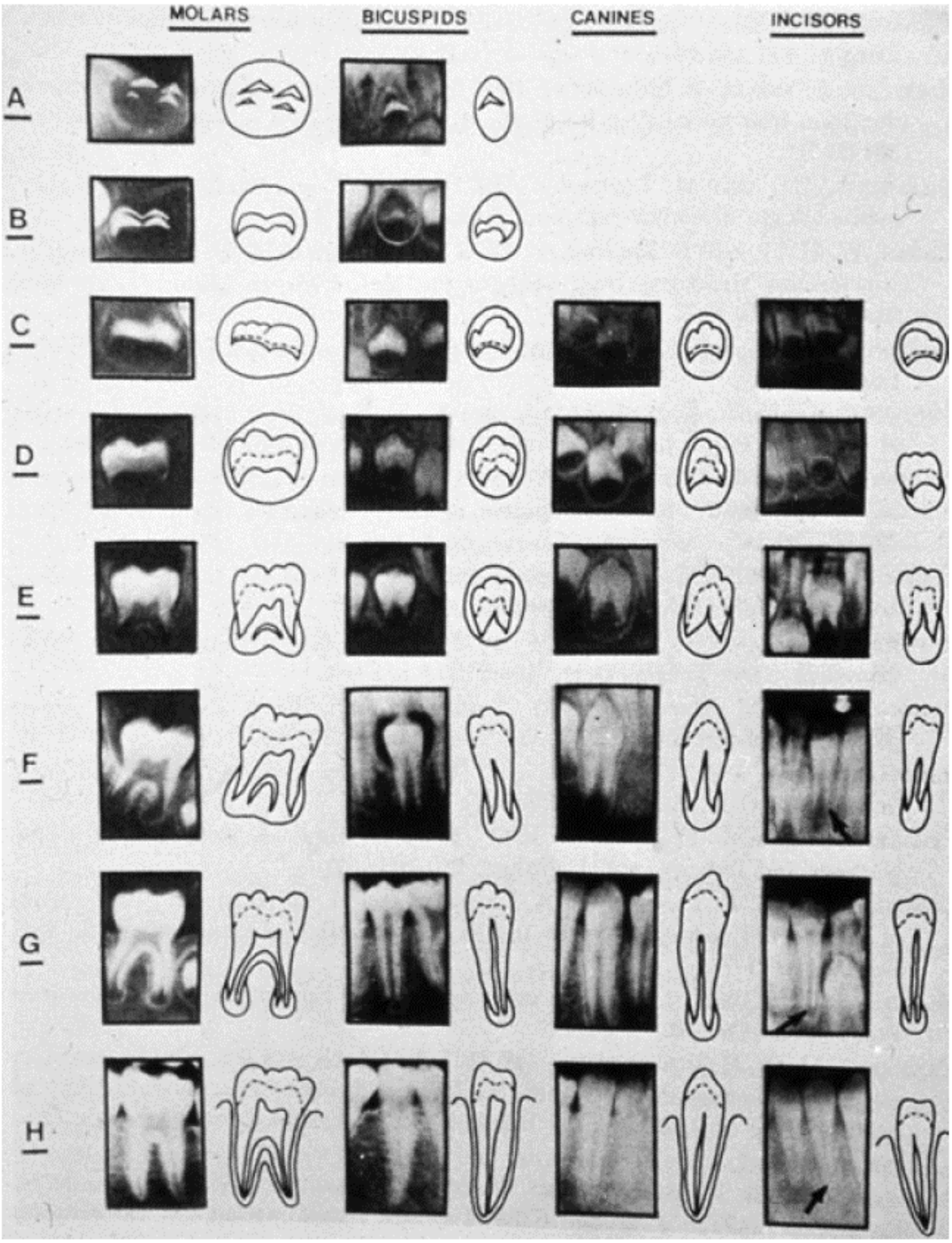
IRAS Project ID: 157962
REC Reference: 15/YH/0110

Appendix 13: Example of clinical photographic views of subjects in this study

FPM 115

Appendix 14: Illustration of Demirjian's Dental Development Stages

(Demirjian et al., 1973)



Appendix 15: Criteria description of Demirjian's Dental Development stages

(Demirjian et al., 1973)

Stage	Description
A	Initial crown calcification, without fusion of different calcification points. In both uni-radicular and multi-radicular teeth, the beginning of the calcification is seen at the superior level of the crypt in the form of an inverted cone or cones.
B	Fusion of mineralization points forms one or several cusps which unite to give a regularly outlines occlusal surface.
C	Occlusal surface completely formed: a. Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen. b. The beginning of a dentinal deposit is seen. c. The outline of the pulp chamber has a curved shape at the occlusal border.
D	Crown formation completed to the level of the cemento-enamel junction: a. The crown formation is completed down to the cemento-enamel junction. b. The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns if present, gives an outline shaped like an umbrella top. In molars the pulp chamber has a trapezoidal form. c. Beginning of root formation is seen in the form of a spicule.
E	The root length remains shorter than the crown height: In uniradicular teeth: a. The walls of the pulp chamber now form straight lines, whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage. b. The root length is less than the crown height. In molars: a. Initial formation of the radicular bifurcation is seen in the form of wither a calcified point or a semi-lunar shape. b. The root length is still less than the crown height.
F	the root length is equal to or greater than the crown height In uniradicular teeth: a. The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape. b. The root length is equal to or greater than the crown height. In molars: a. The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel shaped endings. b. The root length is equal to or greater than the crown height.
G	the apical end of the root canal is partially open: a. The walls of the root canal are now parallel and its apical end is still partially open (distal root in molars).
H	the root apex is completely closed: a. The apical end of the root canal is completely closed dDistal root in molars) b. The periodontal membrane has a uniform width around the root apex.

The stages (A-H) may be defined by one(1), two (2), or three (3) criteria:

- If only 1 criterion is given, it must be met in order to consider that the stage has being attained.
- If 2 criteria are given, then it is sufficient if the first of the 2 is met.
- If 3 criteria is given, then any two of the 3 must be met in order for the stage to be considered attained.

Appendix 16: Self-weighted scores for Demirjian's Dental stages in the revised 7-teeth system for Boys and Girls

(Demirjian & Goldstein, 1976)

Boys

Tooth	Stages 0	A	B	C	D	E	F	G	H
M_2	0·0	1·7	3·1	5·4	8·6	11·4	12·4	12·8	13·6
M_1				0·0	5·3	7·5	10·3	13·9	16·8
PM_2	0·0	1·5	2·7	5·2	8·0	10·8	12·0	12·5	13·2
PM_1		0·0	4·0	6·3	9·4	13·2	14·9	15·5	16·1
C				0·0	4·0	7·8	10·1	11·4	12·0
I_2				0·0	2·8	5·4	7·7	10·5	13·2
I_1				0·0	4·3	6·3	8·2	11·2	15·1

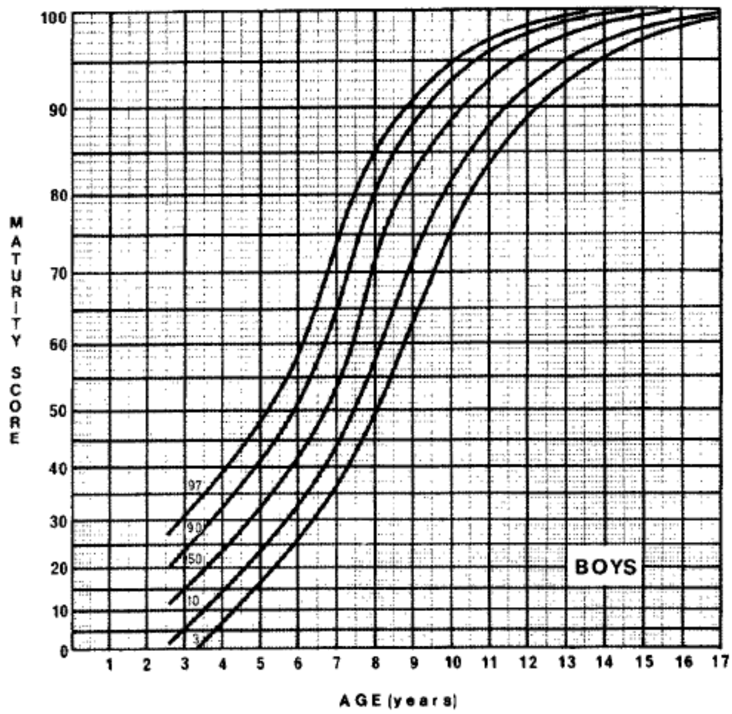
Girls

Tooth	Stages 0	A	B	C	D	E	F	G	H
M_2	0·0	1·8	3·1	5·4	9·0	11·7	12·8	13·2	13·8
M_1				0·0	3·5	5·6	8·4	12·5	15·4
PM_2	0·0	1·7	2·9	5·4	8·6	11·1	12·3	12·8	13·3
PM_1		0·0	3·1	5·2	8·8	12·6	14·3	14·9	15·5
C				0·0	3·7	7·3	10·0	11·8	12·5
I_2				0·0	2·8	5·3	8·1	11·2	13·8
I_1				0·0	4·4	6·3	8·5	12·0	15·8

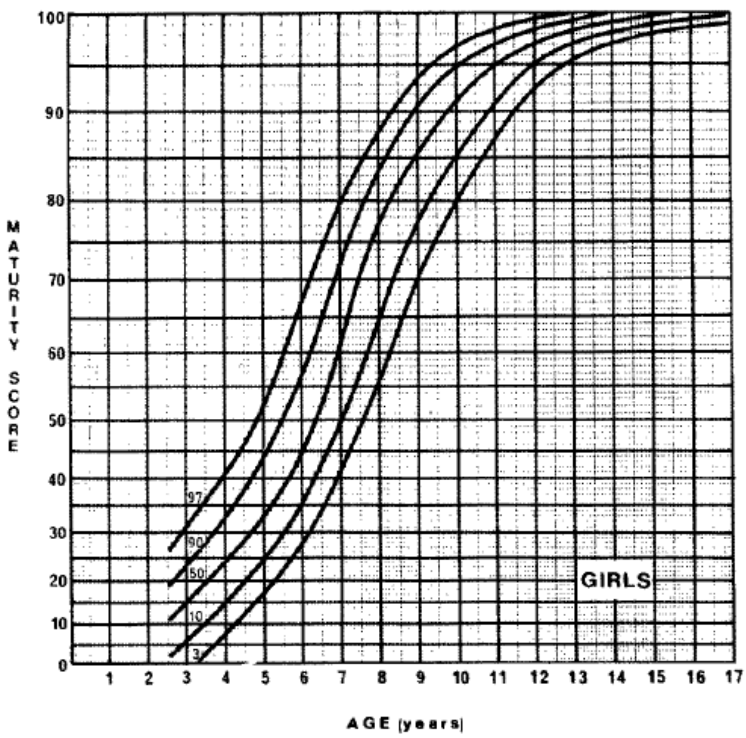
Appendix 17: Demirjian's Dental maturity Percentile charts for the revised 7-teeth method in Boys and Girls

(Demirjian & Goldstein, 1976)

Boys:



Girls:



Appendix 18: Table of median tooth formation stage by age

(Liversidge, 2010)

Liversidge's (2010) study aimed to describe the variation in maturity score for age and age for maturity score from Chaillet's et al (2005) large collaborative database of 9,372 children of European origin in Australia, Belgium, Canada, England, Finland, Sweden, and South Korea, aged 2-18 years old. Clinicians can compare a dental score of an individual child with the 95% confidence interval.

Liversidge (2010) produced a table of median tooth formation stage by age, shown below:

Median stage by year age groups. 2+ includes all individuals from 2.00 to 2.99 years, mature number of individuals with seven teeth in stage H divided by number of individuals in age category.

Age	*N*	I_1	I_2	C	P_1	P_2	M_1	M_2	Mature males	Mature females
2+	38	D	D	C	B	A	D	–		
3+	170	D	D	C	C	A	D	A		
4+	424	E	D	C	C	B	E	B		
5+	516	E	E	D	D	C	F	C		
6+	646	F	F	E	D	D	G	D		
7+	792	G	G	E	E	D	G	D		
8+	922	H	G	F	E	E	G	D		
9+	880	H	H	F	F	F	G	E		
10+	918	H	H	G	F	F	H	F	1/432	
11+	725	H	H	G	G	F	H	F		7/392
12+	809	H	H	H	G	G	H	G	4/399	25/410
13+	686	H	H	H	H	G	H	G	23/333	54/353
14+	583	H	H	H	H	H	H	G	93/316	102/267
15+	470	H	H	H	H	H	H	H	137/249	155/221
16+	363	H	H	H	H	H	H	H	147/170	176/193
17+	326	H	H	H	H	H	H	H	162/171	145/155
18+	104	H	H	H	H	H	H	H	62/63	39/41

The score for a bilaterally missing premolar of a child subject in this current study, was substituted with the values taken from the above table of median tooth formation stage by age, as published by Liversidge (2010).

Appendix 19: Clinician patient-related questionnaire

[10/03/2015, Version 4]

Clinician Questionnaire: Patient-Related

Instructions to the clinician:
This questionnaire is to be completed by you, the clinician, at the Initial consultation appointment, following completion of assessment and treatment plan discussion.
Thank you.

Date of Assessment:......../......./ 20.......

Patient Participation Number: _________

Clinician Participation Number:_________

1) Information about the clinician:

- Position:
  - ☐ Consultant
  - ☐ Specialist or Post-CCST
  - ☐ Postgraduate or Pre-CCST
  - ☐ Dental Core Trainee/
  - ☐ Other...

2) What is the patient's Date of Birth? ..../........../..........

3) Has the patient complained of any current pain or symptoms from their First Permanent Molars? (**FPM**)? ☐Yes ☐No

4) If yes, please give details/diagnosis of the pain/symptoms?

....

....

5) The Referral was for the management of which FPM?

6) Which FPM were actually affected?

7) What was your final diagnosis of the FPM?

....

....

8) Provisional / Agreed plan of the FPM (*please tick all the appropriate boxes and indicate which teeth*)

☐ Extraction of teeth:	
☐ Restoration of teeth:	
☐ Temporisation of teeth:	
☐ Other:.....................	

[10/03/2015, Version 4]

9) Mode of delivery of treatment: (*please tick all the appropriate boxes and indicate which teeth*)

☐ LA ☐ GA ☐ Inhalation Sedation ☐ Other…………………

If treatment planning was undertaken by a senior colleague / supervisor, please ask them to answer the following questions, and document their answers below. Otherwise, please document your own answers.
Thank you!

Information about the senior person responsible for the opinion (if applicable) :

- Name…………………………………………………………………………
- Position:
  ☐ Consultant
  ☐ Specialist or Post-CCST
  ☐ Postgraduate or Pre-CCST
  ☐ Dental Core Trainee
  ☐ Other…………………………………………………………………………

10) Please list the factors, which influenced your treatment planning decision, specifically for this patient, in any order.

Rank	**Factors**	**Quantify the factor for this patient (if applicable)**

11) Please **rank** these factors by order of importance using the column on the left by starting with **1** as the **most important** factor involved in the decision process for this patient.

[10/03/2015, Version 4]

12) Please tick the appropriate box to help rate the overall restorability of the FPM:

Tooth	No Restorative Intervention required	Restorable with good long term prognosis	Restorable with good short term but questionable long term prognosis	Non-restorable, or only restorable in the immediate term
UR6				
UL6				
LR6				
LL6				

Please use the space provided if you have any further comments regarding the restorability of the FPM:

....

....

....

13) Was a formal orthodontist opinion sought?
☐Yes ☐ No

14) Was a Paediatric Dentist opinion sought?
☐Yes ☐ No

15) What radiographs (if any) were used to support the diagnosis?
☐ OPT ☐ BWs ☐ Periapicals ☐ None

16) Patient's Behaviour (Frankl): __________

17) Patient's Oral Hygiene Status:__________

18) Please record the approximate number of minutes it took to complete this form:

☐ Minutes

Thank you for taking the time to fill-out this questionnaire, please feel free to provide additional feedback or opinions regarding this subject matter:

....

....

....

....

....

Appendix 20: Clinical Records Analysis sheet

FPM Study Clinical Records Analysis Sheet

Participant No. FPM ______

Records: ☐Clinical Photos
☐Study Models
☐OPT Radiograph

Gender: ☐Male
☐Female

1) Radiographic anomalies - (OPT Radiograph)

Developmentally missing:	Supernumeraries (S):	Other :

2) Dental Age - (OPT Radiograph) *(Demirjian & Goldstein 7 –teeth method, 1976)*

Tooth Number	M_2	M_1	PM_2	PM_1	C	I_2	I_1	TOTAL
Tooth stage								
Maturity score								
Dental age (years)								*years*

3) Caries Assessment – DMFT & dmft (Clinical Photographs/Clinical charting/Radiographs)

Total 2°	D	M	F	DMFT		*Total 1°*	d	m	f	dmft

D secondary to MIH: ______

4) Enamel Defects– *mDDE index* *(Clarkson and O'Mullane, 1989)* (Clinical Photographs)

FPM: *missing?*	☐ **Normal** (no defect) - *RR?*	☐ **Demarcated:** - White/cream - Yellow/brown	☐ **Other:** - Diffuse - Hypoplasia
INCISORS: Demarcated defect present?	☐No ☐Yes: *(indicate if W or Y)*		**PRIMARY molars affected?** ☐No ☐Yes: ☐not present

Associated Diagnosis: ☐ MIH ☐Caries ☐Other ______________

5) FPM Severity – (clinical photographs +/- radiographs)

IF MIH Diagnosis:

MIH Defect Type:	DO	PEB	AT Cavity or Restoration?	E-MIH	UE
UR6					
UL6					
LL6					
LR6					

MIH Severity:	Mild	Moderate	Severe
UR6			
UL6			
LL6			
LR6			

Total *FPM* affected with MIH: ______

IF CARIES only Diagnosis:

Caries Severity	Restored	1 surface	2 or + surfaces	Into pulp/ RR
UR6				
UL6				
LL6				
LR6				

Total *FPM* affected with Caries: ______

DO = Demarcated opacity
PEB = Post-eruptive breakdown
AT = Atypical restoration
(or Atypical cavity)
E-MIH = Extraction due to MIH
UE = not yet erupted
RR = Remaining Roots

DMFT = permanent teeth
dmft = primary teeth

MIH Severity:

1. *MILD* = demarcated opacities; no loss of enamel; no *AT*.
2. *MODERATE* = enamel opacities with PEB / loss of tooth substance limited to enamel.
3. *SEVERE* = hypomineralised lesions with loss of enamel + dentine; and/or *AT* replacing hard tissue.

Appendix 21: Orthodontic Analysis Sheet

FPM

Orthodontic analysis sheet for FPM Study

<table>
<tr><td>Skeletal Pattern</td><td></td><td>Dental development stage:</td><td>☐ Early mixed dentition (Incisors erupting)
☐ Intermediate mixed dentition
(Incisors fully erupted)
☐ Adolescent Dentition
(Canines and premolars fully erupted)</td></tr>
<tr><td rowspan="4">Occlusal Classification

Sagittal Plane [AP]
- Buccal Segment A-P
- Anterior Segment A-P</td><td>Molar Relationship</td><td colspan="2">Right :   Left:</td></tr>
<tr><td>Incisor Relationship</td><td colspan="2"></td></tr>
<tr><td>Overjet
(a)

Reverse Overjet
(b)</td><td colspan="2">________mm
☐ No increased OJ
☐ Mild OJ >3.5 mm but ≤ 6 mm (IOTN 3 incomp. lips 2 comp. lips)
☐ Moderate OJ > 6 mm but ≤ 9 mm (IOTN grade 4)
☐ Severe OJ > 9mm (IOTN grade 5)

________mm
☐ No Reverse overjet
☐ Mild Reverse OJ > 0 mm but ≤ 1 mm (IOTN grade 2)
☐ Moderate Reverse OJ > 1 mm but ≤ 3.5 mm (IOTN grade 3)
☐ Severe Reverse OJ > 3.5 mm (IOTN grade 4)
Adapted from IOTN</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td rowspan="4">Vertical Plane:
- Open bite
- Over bite</td><td>Overbite
(f)</td><td colspan="2">________ mm
☐ Decreased <1/3 of lower incisor ←Adapted from ICON
☐ Average
☐ Increased >2/3 OR (> 3.5mm) ← Adapted from IOTN</td></tr>
<tr><td>Anterior Open Bite
(e)</td><td colspan="2">________ mm
☐ No open bite
☐ Mild Openbite > 1mm but ≤ 2mm (IOTN grade 2)
☐ Moderate Openbite > 2 mm but ≤ 4 mm (IOTN grade 3)
☐ Severe Openbite > 4 mm (IOTN grade 4)
Adapted from IOTN</td></tr>
<tr><td>Posterior Open Bite
(e)</td><td colspan="2">_______ mm
Type: ☐ unilateral ☐bilateral

☐ No open bite
☐ Mild Openbite < 1mm but ≤ 2mm (IOTN grade 2)
☐ Moderate Openbite > 2 mm but ≤ 4 mm (IOTN grade 3)
☐ Severe Openbite > 4 mm (IOTN grade 4)
Adapted from IOTN</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td rowspan="3">Transverse Plane:
- cross bite
- Midline shift</td><td>Centreline assessment</td><td colspan="2">______ mm
☐ 0 - Coincident and up to ¼ width of the lower incisor
☐ 1- ¼ to ½ width of the lower incisor
☐ 2- Greater than ½ width of the lower incisor
Adapted from PAR</td></tr>
<tr><td>Anterior Crossbite
(c)</td><td colspan="2">☐ no
☐ yes → single tooth / multiple teeth
Adapted from ICON</td></tr>
<tr><td>Posterior Crossbite
(c)</td><td colspan="2">☐ no
☐ yes → single tooth / multiple teeth
→ unilateral / bilateral
Adapted from ICON</td></tr>
</table>

Presence of Crowding:
(d)

Permanent Dentition (premolars erupted)

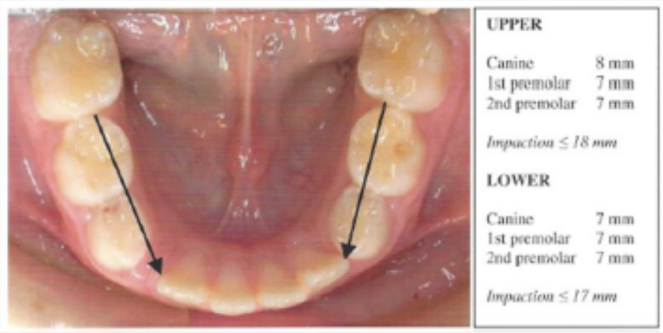
☐ 5 *i* Impeded eruption of teeth due to crowding, displacement, the presence of supernumerary teeth, retained deciduous teeth and any pathological cause.

☐ 4 t Partially erupted teeth, tipped and impacted against adjacent teeth.

☐ 4 d Severe displacement of teeth > 4mm
☐ 3 d Moderate Displacement of teeth > 2mm but to ≤ 4mm
☐ 2 d Mild displacement of teeth > 1 mm but ≤ 2mm

☐ No Crowding/Displacement

Mixed Dentition *(premolars NOT erupted)*



Measure Mesial of 6 to distal of 2

Adapted from Richmond (2008; 1992)

☐ *Measured from C's ?*

UPPER ARCH
- Right side ________mm ☐ Impaction ☐ No Impaction
- Left side ________ mm ☐ Impaction ☐ No Impaction

LOWER ARCH
- Right side ________mm ☐ Impaction ☐ No Impaction
- Left side ________ mm ☐ Impaction ☐ No Impaction

IOTN

(overall score, recording worse occlusal trait)

Dental Health Component (DHC)

M
O
C
D
O

Aesthetic Component (AC)

Appendix 22: Invitation page of the web-based Paediatric Clinicians Survey

Link to survey: https://www.surveymonkey.com/r/FPMstudy

UNIVERSITY OF LEEDS

FPM Study: Clinician-related Questionnaire

Yorkshire and the Humber

Welcome to the FPM Study Survey!

You are kindly invited to complete this online survey, at your convenience. It has been piloted and takes around *5 minutes* to complete.

The purpose of this survey is to investigate how dentists make decisions about the management of defective or carious First Permanent Molars (FPM).

The results of this survey will be used for the purpose of addressing one of the aims of a Doctoral Research Project (*reviewed by the Bradford Leeds Research Ethics Committee with IRAS Project ID: 157962 and REC Reference: 15/YH/0110*).

The results of this data is intended to be published, however, no individuals' identity nor their location within their NHS England regional teams will be revealed. Only collated data will be presented. Data will only be broken-down into broad categories eg. (Hospital vs non-hospital setting) and (consultant vs specialist).

Please answer to the best of your knowledge.

Thank you for participating in the survey. Your response is very valuable.

Ms. Hussa Al-Bahar, Postgraduate in Paediatric Dentistry
Mr. Stephen Fayle, Consultant Paediatric Dentist
Mr. James Spencer, Consultant Orthodontist

Next