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MALOCCLUSION AND ORAL HEALTH RELATED QUALITY OF LIFE

Mohd Masood

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To my parents, wife and daughters

For their unconditional love and support

This accomplishment belongs to you all as well

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ABSTRACT

Mohd Masood

Malocclusion and Oral Health Related Quality of Life

University of Turku, Faculty of Medicine, Institute of Dentistry, Department of Community Dentistry and Finnish Doctoral Program in Oral Sciences (FINDOS-Turku), Turku, Suomi, 2017

Aim was to determine the association between malocclusion and oral health-related quality of life (OHRQoL) and to test and modify the conceptual model of perceived oral health for malocclusion patients.

Two different datasets were used. Malaysian data consisted of a sample of 323 young adult patients seeking orthodontic treatment. Finnish data was obtained from 4085 adult participants of the national Health 2000 Survey. In Malaysian patients, malocclusion was measured using Index of Orthodontic Treatment Need. In the Finnish data, malocclusion was registered using malocclusion traits (increased overjet and overbite, and cross-bite, scissor-bite and open bite). OHRQoL was measured using OHIP-14. The association of malocclusion and OHRQoL was evaluated using multivariable linear and zero inflated Poisson regressions. Modified model of oral health for malocclusion patients was tested using structural equation.

Malocclusion was significantly associated with OHRQoL and of its seven domains, the impact was highest in the psychological discomfort domain. Among adult Finns OHRQoL was significantly poorer in people with overjet. Overjet was associated only with the physical disability domain. Cross-bite and scissor-bite were associated with the social disability domain. Psychological disability was associated with increased overbite and open bite. Fit indexes for previous conceptual model indicated that it did not fit the data well. Therefore, a modified model was developed to incorporate additional paths between levels to better fit the data.

Malocclusion has a negative impact on OHRQoL and its domains. Previous conceptual model of perceived oral health was not found appropriate for people with malocclusion. Thus, an alternative model is proposed.

Key words: Malocclusion, Oral Health Related Quality of Life, Conceptual Model of Oral Health

TIIVISTELMÄ

Mohd Masood

Purentavirheet ja suunterveyteen liittyvä elämänlaatu

Turun Yliopisto, Lääketieteellinen tiedekunta, Hammaslääketieteen laitos, Sosiaalihammaslääketieteen oppiaine, Kansallinen suun terveystieteiden tohtoriohjelma (FINDOS-Turku), Turku, Suomi, 2017

Tutkimuksen tavoitteena oli selvittää purentavirheiden ja suunterveyteen liittyvän elämänlaadun välistä yhteyttä sekä kehittää teoreettinen malli, joka kuvaa koettua suunterveyttä niillä, joilla on purentavirhe.

Tutkimuksessa käytettiin kahta eri aineistoa. Toisen muodostivat 323 malesialaista nuorta aikuista, jotka olivat hakeutuneet oikomishoitoon. Toinen aineisto koostui 4085:stä kansalliseen Terveys 2000 -tutkimukseen osallistuneesta suomalaisesta aikuisesta. Malesialaisten potilaiden purentavirheet mitattiin käyttäen Index of Orthodotic Treatment Need mittaria. Suomalaisilta aikuisilta rekisteröitiin suurentuneet ylipurennat sekä avo-, saksi- ja ristipurennat. Suunterveyteen liittyvää elämänlaatua mitattiin OHIP-14-mittarilla. Purentavirheiden ja suunterveyteen liittyvän elämänlaadun välistä yhteyttä arvioitiin lineaarisella ja nolla-inflatoidulla Poisson regressiomalleilla. Uuden teoreettisen mallin sopivuutta arvioitiin rakenneyhtälömallilla.

Suunterveyteen liittyvään elämänlaatu oli huonompi niillä, joilla oli jokin purentavirhe. Elämänlaadun seitsemästä osa-alueesta yhteys oli vahvin psyykkisen epämukavuuden alueella. Suomalaisten aikuisten purentavirheistä suurentunut horisontaalinen ylipurenta huononsi suunterveyteen liittyvää elämänlaatua erityisesti fyysisen haitan osa-alueella. Ne, joilla oli risti- tai saksipurenta, kokivat useammin sosiaalista haittaa. Ne, joilla oli avo- tai syväpurenta, kokivat useammin psykologista haittaa. Tilastollisessa analyysissä käytetyn rakenneyhtälömallin perusteella aiempi teoreettinen malli ei ollut tässä aineistossa sopiva. Tämän vuoksi teoreettista mallia muokattiin lisäämällä uusia osa-alueiden välisiä yhteyksiä, jotta malli sopi paremmin kuvaamaan purentavirheiden vaikutusta.

Purentavirheet näyttäisivät huonontavat suunterveyteen liittyvää elämänlaatua ja sen osa-alueita. Uusi teoreettinen malli kuvaa paremmin purentavirheiden vaikutusta koettuun suunterveyteen.

Avainsanat: purentavirhe, suunterveyteen liittyvä elämänlaatu, suunterveyden teoreettinen malli

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ABBREVIATIONS

OHRQoL	Oral Health Related Quality of Life
OHIP-14	Oral Health Impact Profile -14
PROs	Patient-reported outcomes
QoL	Quality of Life
HRQoL	Health Related Quality of Life
IOTN	Index of Orthodontic Treatment Need

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following articles, which are referred to in the text by roman numerals I-IV. The original publications have been reproduced with the permission of the copyright holders.

I. **Masood, M.**, Suominen, A. L., Pietila, T., & Lahti, S. (2017). Malocclusion traits and oral health-related quality of life in Finnish adults. Community Dentistry and Oral Epidemiology, 45(2), 178-188. doi:10.1111/cdoe.12276

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1 INTRODUCTION

Malocclusion and orthodontic treatments differ from the majority of medical and dental conditions and interventions, malocclusion is ‘a set of dental deviations’ and orthodontic treatment does not cure a condition; but rather corrects variations from an arbitrary norm (O'Brien et al. 2007b). This has led to a debate about defining the point at which the extent of variation means that orthodontic treatment is desirable (Petersen et al. 2005). Further, it has been suggested that the majority of oral health measures developed in dentistry are not applicable to orthodontic patients because most malocclusions are asymptomatic and related to aesthetics, as opposed to features of other diseases (O'Brien et al. 2007b). Additionally, a malocclusion can be perceived differently by the affected person, and a person’s self-awareness of the malocclusion might not be related to its functional problem (Feu et al. 2010b).

Need assessment for orthodontic treatment in dental clinics is traditionally normatively assessed using various clinical measures including the Index of Orthodontic Treatment Need (IOTN) (Feu et al. 2010b; Onyeaso 2009). However, there is evidence that many adolescents with normative orthodontic treatment need measured by IOTN experienced no perceived need (Bernabe et al. 2008b; de Oliveira and Sheiham 2003). Therefore, the use of these clinical measures alone to establish the need for orthodontic treatment may be potentially problematic since some patients who do not actually have psychosocial need for treatment would be treated according to their IOTN (De Baets et al. 2011b; Kok et al. 2004). Therefore, when evaluating the impact of a malocclusion, it is important to consider the different domains that can be affected and their relationships to the severity of malocclusion. Some people with a severe malocclusion are satisfied with or indifferent to their dental esthetics, whereas others are concerned about minor irregularities (Feu et al. 2010b). However, the use of Oral Health Related Quality of Life (OHRQoL) measures in addition to professional indices becomes a very useful combination in orthodontic treatment need assessment and their perceived benefit (Johal et al. 2007; Onyeaso 2009).

OHRQoL is a multidimensional construct that corresponds to the impact of oral health or diseases on an individual’s daily functioning, well-being or overall quality of life (Locker and Allen 2007). Conditions affecting oral health, such as dental caries and periodontitis, including malocclusion, are highly prevalent, and have consequences not only for physical and economic well-being, but can also impair the quality of life by affecting function, appearance,

interpersonal relationships, socializing, self-esteem and psychological well-being (Silvola et al. 2012; Silvola et al. 2014).

Despite the fact that malocclusion places a significant burden on oral health care provision globally, evidence on impact of malocclusion and orthodontic treatment need on the quality of life is still conflicting (Liu et al. 2011). Some authors found a strong relationship between malocclusion or orthodontic treatment need and OHRQoL (Foster Page et al. 2005; Johal et al. 2007; Locker et al. 2004). Most of the studies that report an association between malocclusion and OHRQoL have relatively low strength of evidence (Andiappan et al. 2015; Liu et al. 2011). Some of the studies did not find any association between malocclusion and the quality of life (Arrow et al. 2011; de Oliveira et al. 2008; Kenealy et al. 2007; O'Brien et al. 2007b; Zhang et al. 2006).

Additionally, the available evidence does not provide a complete picture of the impact of malocclusion on OHRQoL at the population level as majority of previous studies were focused on small samples of children or adolescents from clinical settings. However, very little work has been done on adults (Andiappan et al. 2015; Silvola et al. 2012). Although studies have shown that patients seeking orthodontic care have poorer OHRQoL than general population, the association between malocclusion and OHRQoL among adults not seeking orthodontic treatment is still unclear (Silvola 2014b). This is important from a public health perspective, especially for a broader evaluation of need assessment and for planning public health policies. It is also important in planning healthcare services for prioritization of care, especially where public healthcare resources are limited (Lahti et al. 2008; Scapini et al. 2013). Therefore, it is important to assess the impact of malocclusion on OHRQoL in adults from a nationally representative sample, especially with regards to the possible effects of other clinical and socioeconomic variables.

In 1988, Locker outlined a model of OHRQoL based on the World Health Organization conceptualization of the impact of disease. Since then, much of the research including research on malocclusion or orthodontic treatment and OHRQoL has been based implicitly on this model (Locker 1988). Locker's model has typically been viewed as a framework rather than as a scientific model to be empirically validated. There have been few studies that attempted to test the model pathways explicitly (Baker 2007; Nuttall et al. 2006). These have included the oral health of the general adult population, as well as the impact of being edentulous and of dental caries experience (Baker 2007; Baker et al. 2007; Baker et al. 2008; Nuttall et al. 2006). However, to date it has not been determined whether, for malocclusion patients, the constructs in Locker's model relate to one another as hypothesized. There are

several reasons why the model may differ in this patient group. First, malocclusion and orthodontic treatments differ from the majority of oral and dental diseases or conditions (O'Brien et al. 2007a). Further, it has been suggested that the majority of oral health measures developed in dentistry are not applicable to orthodontic patients because most malocclusions are asymptomatic and related to aesthetics, as opposed to features of other diseases (O'Brien et al. 2007a; Rusanen et al. 2010). In addition, evidence suggests that social and psychological effects are the key motives for seeking orthodontic treatment rather than function limitation or pain or discomfort (Hassan and Amin Hel 2010a). However, few studies suggested other motivating factors, such as temporomandibular disorders, headache and reasons related to self-esteem and self-confidence (Pabari et al. 2011). Therefore, it was hypothesized that the pathways in Locker's conceptual model are not applicable to malocclusion patients in the manner suggested for other oral diseases. Consequently, it is important to consider the different domains that can be affected and their relationships to malocclusion, since it sheds light on the effects of malocclusion on people's lives and provides more understanding of the reasons that lead to the demand for orthodontic treatment. Developing knowledge of key pathways will help facilitate the design of intervention strategies, for example; guiding clinicians as to where and how to intervene most effectively in patients with malocclusion(Baker et al. 2008). Finally, on-going development of the OHRQoL, as in any field of inquiry, requires key concepts to the explored and disentangled. Only by testing the empirical validity of a model can alternatives be proposed to address any identified weaknesses (Baker 2007).

2 REVIEW OF LITERATURE

2.1 Occlusion

The Academy of Prosthodontics, 2005 defines the term ‘occlusion’ as the static relationship between the incising or masticating surfaces of maxillary and mandibular teeth intercuspate between each other in all mandibular positions and movements (Ash and Ramfjord 1982). Discussion on occlusion often includes two main aspects of occlusion, ideal occlusion and normal occlusion. An ideal occlusion is a condition when the skeletal bases of maxilla and mandible are of the correct size relative to each other and the teeth are placed in correct relationship in all three planes of space at rest (McDonald and Ireland 1998). However, an ideal occlusion is rarely found, therefore, normal occlusion is considered as a better reference when talked about occlusion and malocclusion (Hassan and Rahimah 2007).

The first widely known concept of ‘normal’ occlusion was proposed by Edward H. Angle (Angle 1899): ‘in normal occlusion, the mesio-buccal cusp of the upper first molar is received in the sulcus between the mesial and distal buccal cusps of the lower first molar. Later, Andrews, 1972 added six keys to normal occlusion; molar relationship, crown angulation, crown inclination, rotations, Spaces, occlusal plane (Andrews 1972). In addition to these static features of occlusion given by Angle and Andrews, Roth described the philosophy of ‘ideal’ occlusion based on the dynamic features of occlusion during functional movement (Roth 1981). During functional movement, the following occlusal characteristics should be evident: Centric relationship and centric occlusion should be coincident; In protrusion, the incisors should disclude the posterior teeth, with the guidance being provided by the lower incisal edges along the palatal contour of the upper incisors; In lateral excursions of the mandible, the canine should guide the working side whilst all other teeth on that side and the other side should be discluded; When the teeth are in centric occlusion, there should be even bilateral contacts in the buccal segments (Roth 1981).

For the need assessment purpose, in a recent definition, Houston et al. (1992) defined normal occlusion as an occlusion within the accepted deviation of the ideal and did not constitute aesthetic or functional problems (Houston et al. 1992). However, it is not possible to specify precisely the limits of normal occlusion as long as there is no evidence that deviation could be disadvantageous to the patient (Hassan and Rahimah 2007). Therefore, considerable controversies exist with respect to the concept of ‘normal’ occlusion and to what extent deviations from the ‘ideal occlusion’ should be considered as normal and what should be

considered abnormal (Proffit et al. 2007). Current research suggests that defining 'normal' occlusion and malocclusion should consider wider aspects including its multi-factors, such as morphology, function, psychology, sociology (Liu 2009; Proffit et al. 2007).

2.2 Malocclusion

The term malocclusion has been included under the heading of 'Handicapping Dentofacial Anomaly' by World Health Organization, who define the anomaly as that which causes disfigurement or which impedes function and requires treatment if the disfigurement or functional defect is likely to be an obstacle to the patient's physical or emotional well-being (WHO 1992). The simplest definition of malocclusion is 'a set of deviations from standards of normal occlusion' rather a disease (O'Brien et al. 2007b; Proffit et al. 2007). Proffit (2007) elaborated that malocclusion might be associated with anomalies within the dental arches, imperfect positioning of the teeth/tooth when the jaws are closed (i.e. crowding and spacing tipped, displaced, rotated, in infra-occlusion, in supra-occlusion and transposed), mal-relation of dental arches (i.e. anteroposterior, vertical and transverse anomalies) and skeletal discrepancies (Mtaya 2008; Proffit et al. 2007).

2.3 Classification of Malocclusion

Although there is an agreement that malocclusion refers to a significant deviation from the standard of normal occlusion but the diversity of the deviation and difficulty to agree upon a certain cut-off points makes its classification extremely difficult (Liu 2009). This has resulted in numerous different ways of classifications of occlusion and malocclusion such as Angle, 1899 (Angle 1899); Björk et al., 1964 (Björk et al. 1964); Ackerman and Proffit, 1969 (Ackerman and Proffit 1969); Baume et al., 1973 (Baume et al. 1973); Little, 1975 (Little 1975); Bezroukov et al., 1979 (Bezroukov et al. 1979); British Standards Institution, 1983 (British Standard Institution 1983).

All these classifications have some advantages and disadvantages. For instance, Angle's classification is still a commonly used method for registration of malocclusion; however, it only takes into account the antero-posterior deviations (Hassan and Rahimah 2007). Similarly, epidemiological registration of malocclusion developed by Björk et al. (1964) records different malocclusion traits, but gives little emphasis on treatment need (Björk et al. 1964; Silvola 2014a). British Standards Institution classification is based mainly on the incisor relationship and no consideration is made for molar relationship (British Standard Institution 1983). Ackerman and Proffit classification (Table 1) overcame the weakness of Angle's scheme in several aspects as it included the transverse and vertical as well as antero-posterior planes in classifying malocclusion (Ackerman and Proffit 1969). It also incorporated information about

skeletal jaw proportions in each of the three plans. In addition, it incorporated an evaluation of crowding and asymmetry within the dental arches (Liu 2009).

Table 1: Ackerman and Proffit's malocclusion classification (Ackerman and Proffit 1969)

Dentofacial Appearance
Frontal and Oblique facial proportion, anterior tooth display,
Orientation of the esthetic line of occlusion, profile
Alignment
Crowding/ spacing, arch form, symmetry, Orientation of the functional line of occlusion
Anterio-posterior
Angle's classification, skeletal and dental
Transverse
Cross-bite, skeletal and dental
Vertical
Open-bite, Skeletal and dental

As discussed by Ackerman and Proffit classification, it is important to consider all the three planes in clinical examination. These three planes include various malocclusion traits; for example, increased or reverse overjet indicate antero-posterior deviations in occlusion, deep bite and open bite show vertical deviations, and posterior cross-bite or scissors bite suggest transversal deviations from normal occlusal relationships (Silvola 2014a; Silvola et al. 2012).

2.4 Prevalence of Malocclusion

Malocclusions are highly prevalent in different age groups in many populations (Bock et al. 2011; Brunelle et al. 1996; Buttke and Proffit 1999; Pietilä and Norbland 2008; Salonen et al. 1992; Silvola 2014a; Thilander et al. 2001). Global estimates of malocclusion prevalence are higher than 70% (Liu 2009). Malocclusions in the permanent dentition have been reported to range from 39% in Indian (Dhar et al. 2007) to 98% in Tanzanian children (Mtaya 2008). The reported prevalence of malocclusions is between 43 and 78% in schoolchildren (Dimberg et al. 2015; Myllarniemi 1970; Thilander and Myrberg 1973). Many studies have reported a wide range of prevalence of malocclusion in different populations, different ethnic groups, different age groups or different malocclusal traits (al-Emran et al. 1990; Ciuffolo et al. 2005; Josefsson et al. 2007; Ng'ang'a et al. 1996; Onyeaso 2004; Thilander et al. 2001). The most common malocclusion traits are anterior open bite, excessive overjet, Class II malocclusions, crowding and posterior crossbite (Bourzgui et al. 2012; Dimberg et al. 2015; Sidlauskas and Lopatiene 2009; Thilander and Myrberg 1973; Warren et al. 2005) The prevalence of malocclusion or its

traits varies highly according to the country, ethnic differences, age range (Abu Alhaija et al. 2005) the indices and the criteria used to measure the malocclusion (Thilander et al. 2001).

Studies from Scandinavia reported that prevalence of orthodontic treatment need among adults was around 65% (Burgersdijk et al. 1991; Salonen et al. 1992). In Asian population, a community sample investigation suggested that 50% of the adult population had a definite orthodontic treatment need and almost 30% of this sample had a moderate orthodontic treatment need (Liu et al. 2011; Soh and Sandham 2004). In the U.K., the Child Dental Health Survey in 1993 estimated that approximately 66% of 12-year-olds required some form of orthodontic treatment, and 33% required complex orthodontic treatment (Klages et al. 2005). Further, the 1994-1995 UK National Health Services Dental Survey found a definitive treatment need, in 25.6% of l4-year-olds sampled (Bernabe et al. 2008b). In US, approximately 50-70% of white adult population has at least moderate degrees of malocclusion. Class II malocclusion is frequent in white and blacks compared to Asians, whereas Class III had higher prevalence in Asians compared to blacks or whites. Class III malocclusion in white adult population was estimated to be about 4%, Class II being most prevalent. Deep bite was found in 13% and severe open bite in less than 1% of the white adult population (Proffit et al. 1998). The statistics are not that different for French Canadian children (Barbosa and Gaviao 2008). Using the Grainger's Orthodontic Treatment Priority Index, 32% of the Quebec children surveyed were Angle's class II; 18% had an overjet of 5 mm and over; and 50% had one or more teeth in minor or major displacement (Agou 2009; Agou et al. 2011).

In Finnish adults, 31% to 39.5% of dentate adults had at least one malocclusion trait (Krooks et al. 2016; Pietilä and Norbland 2008). The most common malocclusion traits were lateral crossbite (17.9%), overbite >6mm (11.7%) and overjet>6mm (9.7%). Regarding the vertical incisal relationship, the prevalence of overbite>7mm (2.2%) was higher than that of anterior open bite (1.3%). In the sagittal plane, overjet>9mm (1.3%) was almost as rare as negative overjet (1.2%). In the transverse plane, lateral crossbite was more frequent (17.9%) than scissors bite (7.6%). (Krooks et al. 2016). In Malaysia, a series of epidemiological nation surveys have been conducted by the government of Malaysia (Dental Division, Ministry of Health. Malaysia, 1972,1982, 1986, 1989) (Esa et al. 2001). These surveys have reported the prevalence and severity of one or more types of dentofacial anomalies. The treatment needs reported from these surveys varied from 21% to over 55%. No specific index for malocclusion was utilised in these surveys, therefore these findings could not be used to assess exact treatment needs and priority. Several studies were conducted to measure the malocclusion prevalence and severity in specific communities in Malaysia. A study from a nationally representative sample showed that 62.6% people had minor or no malocclusion traits, 19.6%

had definite malocclusion, 10.6% had severe malocclusion and 7.2% had handicapping malocclusion using the cut-off points for the malocclusion severity levels as proposed by Jenny and Cons (1996) (Esa et al. 2001; Jenny and Cons 1996).

2.5 Measures of malocclusion and orthodontic treatment need

Like classification, over time, numerous assessments of malocclusion have been proposed and this in part again relates to differences in how much deviation is acceptable from the standard of normal occlusion (Björk et al. 1964; Summers 1971). Therefore, most of the measures of malocclusion such as IOTN are not mainly based on the existence of any malocclusion but rather on the need for orthodontic intervention for treating the malocclusion feature (Daniels and Richmond 2000; Liu 2009).

Some of the measures used to assess malocclusion are Björk's method for registration of malocclusion (Björk et al. 1964); the Occlusal Index of Summer's (Summers 1971); Treatment Priority Index (TPI) (Grainger 1967); the Dental Aesthetic Index (DAI) (Cons et al. 1986); the Index of Complexity, Outcome, and Need (ICON) (Daniels and Richmond 2000); the Peer Assessment Rating (PAR) Index (Richmond et al. 1992a) and Index of Orthodontic Treatment Need (IOTN) (Brook and Shaw 1989).

DAI, ICON and IOTN are the most commonly used measures for malocclusion and treatment need in clinical and research settings. DAI has been integrated into the international guideline of oral health survey by the World Health Organization in assessing orthodontic treatment need (WHO 1997). ICON was proposed as a multipurpose occlusal index, which could be used to assess the orthodontic treatment need and complexity of orthodontic treatment but is mainly used to assess improvement from orthodontic treatment (Liu 2009). IOTN is one of the most commonly used malocclusion indices in research and clinical setting for children and adults. Therefore, IOTN was used in this thesis. IOTN consists of two components – the Dental Health Component (DHC) and the Aesthetic Component (AC). The IOTN-DHC cutoff points are important in determining treatment need, for example, some countries use a cut-off point (usually IOTN 4 or 5) in the IOTN to determine treatment eligibility for public funded orthodontic treatment. This fails to take account of the subjective impact of malocclusion. The DHC and AC are used as independent research variables in studies assessing normative and perceived orthodontic treatment need (Liu et al. 2011; Silvola et al. 2012). DHC records various occlusal traits hierarchically. When two or more occlusal traits exist, the trait with the highest hierarchical grading is used in determining the DHC score. The DHC has five grades ranging from 'no need' to 'very great need'. A grade is allocated according to the severity of the worst single occlusal trait and describes the priority for treatment (Borzabadi-Farahani 2011). A

modified method of IOTN for epidemiological surveys was proposed by Burden et al. (2001) (Burden et al. 2001). By using the modified IOTN, every case with IOTN DHC ≥4 and/or IOTN AC ≥ 8 is classified as being in need of treatment. This modification has proved useful in increasing the reliability of IOTN by non-specialists in oral health surveys. The AC of IOTN consists of a group of ten photographs showing different levels of dental attractiveness, based on which a patient's dental aesthetics can be compared. Grade 1 represent the most attractive occlusion and 10 the least attractive occlusion (Brook and Shaw 1989).

Table 2: Index of orthodontic treatment need, dental health component (Brook and Shaw 1989)

Grade 1 - No treatment needed

1. Extremely minor malocclusions, including displacements less than 1 mm

Grade 2 - Little treatment required

2.a Increased Overjet > 3.5 mm but <= 6 mm (with competent lips)
2.b Reverse overjet greater than 0 mm but <= 1mm
2.c Anterior or posterior crossbite with <= 1mm discrepancy between retruded contact position and intercuspal position
2.d Displacement of teeth > 1mm but <= 2mm
2.e Anterior or posterior open bite > 1mm but <= 2mm
2.f Increased overbite >= 3.5mm (without gingival contact)
2.g Pre- normal or post normal occlusions with no other anomalies. Includes up to half a unit discrepancy

Grade 3 – Borderline treatment needed

3.a Increased overjet > 3.5 mm but <= 6 mm (incompetent lips)
3.b Reverse overjet greater than 1 mm but <= 3.5mm
3.c Anterior or posterior crossbites with >1mm but <= 2mm discrepancy between the retruded contact position and intercuspal position
3.d Displacement of teeth >2mm but <=4mm
3.e Lateral or anterior open bite > 2mm but <= 4mm
3.f Increased and incomplete overbite without gingival or palatal trauma

Grade 4 – Great treatment needed

4.a Increased overjet > 6mm but <= 9 mm
4.b Reverse overjet > 3.5 mm with no masticatory or speech difficulties
4.c Anterior or posterior crossbites with > 2 mm discrepancy between the retruded contact position and intercuspal position
4.d Severe displacements of teeth > 4
4.e Extreme lateral or anterior open bites > 4 mm
4.f Increased and complete overbite with gingival or palatal trauma
4.g Less extensive hypodontia requiring pre-restorative orthodontics or orthodontic space closure to obviate the need for a prosthesis
4.h Posterior lingual crossbite with no functional occlusal contact in one or more buccal segments
4.i Reverse overjet > 1 mm but < 3.5 mm with recorded masticatory and speech difficulties
4.j Partially erupted teeth, tipped and impacted against adjacent teeth
4.k Existing supernumerary teeth

Grade 5 – Very great treatment needed

5.a Increased overjet > 9 mm
5.h Extensive hypodontia with restorative implications (more than one tooth missing in any quadrant requiring pre-restorative orthodontics)
5.i Impeded eruption of teeth (apart from 3rd molars) due to crowding, displacement, the presence of supernumerary teeth, retained deciduous teeth, and any pathological cause
5.m Reverse overjet > 3.5 mm with reported masticatory and speech difficulties
5.p Defects of cleft lip and palate
5.s Submerged deciduous teeth

2.6 Need for including patient's perceptions or patient-based measures

The definition of health by World Health Organization includes physical, emotional, and social wellbeing (WHO 1946). To encompass all these dimensions of health in oral health, the Department of Health in England defined oral health as “the standard of oral and related tissue health that enables individuals to eat, speak, and socialize without active disease, discomfort, or embarrassment, and that contributes to general wellbeing” (Great Britain. Department of 1994). Currently, FDI World Dental Federation defines oral health as “Is multi-faceted and includes, but is not limited to, the ability to speak, smile, smell, taste, touch, chew, swallow and convey a range of emotions through facial expressions with confidence and free from pain or discomfort, and disease of the craniofacial complex” (FDI. 2016). This concept of health encouraged the clinician and researchers to supplement that the clinical measures of diseases with patient’s perceived health measures through the individual's perspective (Agou 2009). Need assessment for orthodontic treatment is traditionally normatively assessed using the above-mentioned clinical measures such as the IOTN (Feu et al. 2010b; Onyeaso 2009). These clinical measures focus on clinical outcomes, such as Andrew’s six keys of occlusion (Richmond et al. 1992b). However, there is evidence that many people with normative orthodontic treatment need measured by IOTN do not have any perceived need for the treatment (experienced no impacts on their OHRQoL) (Bernabe et al. 2008b; de Oliveira and Sheiham 2003). However, people usually seek orthodontic treatment for functional and aesthetic worries related to their teeth and how this might affect their interaction with other people and their community (Patel et al. 2016). Additionally, a malocclusion can be perceived differently by the affected person, and a person’s self-awareness of the malocclusion might not be related to its severity (de Oliveira et al. 2008; Feu et al. 2010b). Some people with a severe malocclusion are satisfied with or indifferent to their dental aesthetics, whereas others are concerned about minor irregularities (Feu et al. 2010b). Therefore, the use of these clinical measures alone to establish orthodontic treatment need may be potentially problematic since some patients who do not actually have psychosocial need for treatment would be treated according to their IOTN (De Baets et al. 2011b; Kok et al. 2004). Changes in the need assessment over the past 20 years have highlighted the importance of delivering high quality care after also taking into consideration the perceived need from the patients. Successive policies have given increasing emphasis on improving the quality of care and evaluating the success of treatments from the patient’ s perspective with patient-reported outcomes or PROs (Department of Health 2008; Patel et al. 2016).

Malocclusion has some additional reasons that make it necessary to include an individual's perspectives in need assessment. Malocclusion is an appreciable deviation from the normal occlusion, it is neither a normal or unhealthy condition (Houston et al. 1992). Therefore, orthodontic treatment is different from most other medical interventions in that it does not cure or treat a condition; rather it aims to correct these variations from an arbitrary norm (O'Brien et al. 1998). It exists on a continuum with no clear or simple division as to when treatment becomes desirable (Agou 2009). This has led to a debate about defining the point where the extent of variation means that orthodontic treatment is desirable (Petersen et al. 2005). It is important not to equate the possession of malocclusion with the need for a treatment; instead it should be judged according to dental health, aesthetic or functional criteria namely: chewing, speech, breathing and swallowing (Hassan and Rahimah 2007). Influenced by this concept, there is an increasing consensus that malocclusion should be defined not only by its various anatomic characters but also by its influence on people's physical, social, emotional well-being and overall quality of life (Hassan and Rahimah 2007; Liu 2009; Proffit et al. 2007). Even though treatment need measures take into account some patient's views, none of them take more holistic and theory/model based look and thus, there is a need to include QoL measure in orthodontics if we are aiming for treatment of malocclusion, and not appearance only.

2.7 Quality of life and Oral health related quality of life

Quality of life (QoL) is a vague concept, with usage across many disciplines from philosophy, geography, economics, media to the medical, dental and social sciences (Bowling, 1995). The World health Organization quality of life groups defines quality of life as "an individual's perception of his/her position in life in the context of culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" (WHOQOL 1995).

Gough et al (1983) described the key components of QoL as health, emotion responses and economics. In the 1990's, the term 'Health-related quality of life' (HRQoL) was coined to give precise rather than loose meaning of QoL in health research (Gough et al. 1983). Others have expanded the concept by defining HRQoL as "subjective perception of the impact from health or disease or its treatment across the physical, psychological and social domains of functioning and well-being" (Leplege and Hunt 1997; Revicki et al. 2000).

It has been suggested that the concept of HRQoL should be wider and other domains should also be included (Fitzpatrick et al. 1999). A widely accepted contemporary concept of HRQoL is that of Spilker (1996) who proposed that, where possible, the following domains should be included in assessing HRQoL: i) physical status; ii) psychological status and well-being; iii)

social interactions; iv) economic and/or vocational status and factors; v) religious and/or spiritual status (Liu 2009; Liu et al. 2011; Spilker 1996).

Similarly, there seems to be an implicit assumption that since OHRQoL measures address aspects of daily life that are compromised by oral disorders, they must reflect how these disorders affect the QOL (Albino et al. 1994). The conceptualization of OHRQoL mirrors that of HRQoL except in referring to conditions of the orofacial regions. One of the earliest definitions was provided by Kressin (1997) who defined OHRQoL, in broader terms, as "encompassing the traditional definition of oral health, as well as individual's subjective impact of oral health and well-being and functioning in everyday life" (Kressin et al. 1997). The Surgeon General of the USA reported in 2000 that OHRQoL "derives from a multidimensional construct that reflects people's comfort when eating, sleeping and engaging in social interaction; their self-esteem; and their satisfaction with respect to oral health" (USA Department of Health and Human services, 2000). Locker et al. (2000) describes OHRQoL as the "extent to which oral disorders affect functioning and psychosocial well-being" and "as the symptoms and functioning and psychosocial impacts that emanate from oral diseases and disorders" (Locker et al. 2004). Locker and Allen (2007) have defined OHRQoL as 'a multidimensional concept that includes subjective evaluation of the perceived physical, psychological and social aspects of oral health' and further as 'the impact of oral disorders on aspects of everyday life that are important to patients and persons, with those impacts being of sufficient magnitude, whether in terms of severity, frequency or duration, to affect an individual's perception of their life overall' (Locker and Allen 2007). Then, Inglehart defined OHRQoL more specifically as "the absence of negative impacts of oral conditions on social life and a positive sense of dentofacial self-confidence" (Inglehart and Bagramian 2002). In this definition, Inglehart embraced the central dimensions of OHRQoL. These suggest that OHRQoL be defined as a person's assessment of how the following factors affect his or her wellbeing: (a) functional factors; (b) psychological factors; (c) social factors; and (d) the experience of pain/discomfort. When these considerations centre on oro-facial concerns, OHRQoL is assessed (Inglehart and Bagramian 2002).

2.8 How malocclusion impacts quality of life of the people

Evidence shows that the conditions affecting oral health, including malocclusion, have consequence not only for physical and economic well-being, but can also impair the quality of life by affecting function, appearance, interpersonal relationships, socializing, self-esteem and psychological well-being (Hassan and Amin Hel 2010b). Different studies investigated different levels of malocclusion severity and its impact on OHRQoL. Presence of malocclusion generally reduces the OHRQoL of people when compared with people who have normal occlusion

(Hassan and Amin Hel 2010b; Liu et al. 2011; Rusanen et al. 2010). Furthermore, the severity of malocclusion reportedly associates with poorer OHRQoL (Feu et al. 2010b; Hassan and Amin Hel 2010b; Traebert and Peres 2005). Some authors found a strong relationship between malocclusion or orthodontic treatment need and OHRQoL (Foster Page et al. 2005; Johal et al. 2007; Locker et al. 2004). For instance, the prevalence of oral impacts for children with definite need for orthodontic treatment was twice that for children with no or slight need for orthodontic treatment (Bernabe et al. 2008b). Similarly, Australian children who had less acceptable occlusal traits reported poorer OHRQoL (Do and Spencer 2008). However, some studies didn't find any association between malocclusion and QoL (de Oliveira et al. 2008; O'Brien et al. 2007b; Zhang et al. 2006). A study of British children found that children with malocclusion did not have any significant impact on QoL (Bernabe et al. 2008b). In a cohort study of Arrow et al. (2011), the occlusal status appeared to have limited association with QoL (Arrow et al. 2011). Previous research exploring the relationship between malocclusions and OHRQoL, as well as the impact of orthodontic treatment on OHRQoL has been equivocal. Most studies in the orthodontic literature on OHRQoL use small convenience samples, which limits their evidence (Kragt et al. 2015). In 2006, Zhang et al emphasized the impact of heterogeneous population groups and measurement tools on the conflicting evidence in orthodontic OHRQoL research (Kragt et al. 2015; Zhang et al. 2006). Although studies have shown that patients seeking orthodontic care have poorer OHRQoL compared to normal population, the association between malocclusion and OHRQoL among adults not seeking orthodontic treatment is still unclear.

Systematic reviews and meta-analysis measuring the association of malocclusion demonstrated modest level of association (Liu et al. 2009). A meta-analysis based on 40 cross-sectional studies showed that OHRQoL was lower in children with malocclusions. The summary odds ratio for having an impact on OHRQoL was 1.74 times higher in children with malocclusion than in children without malocclusions (Kragt et al. 2015). Another meta-analysis revealed that OHIP-14 scores were significantly lower in individuals without malocclusion/orthodontic treatment need compared to those with such condition (Andiappan et al. 2015). A recent meta-analysis on malocclusions, orthodontic treatment and OHRQoL in adults found a moderate increase of OHRQoL after treatment, but the difference in OHRQoL between people with and people without malocclusion was small (Andiappan et al. 2015). All these reviews suffered from the considerable differences in study design, heterogeneity and mediocre quality of the studies.

Some studies explored the effect of malocclusion on specific domains of QoL. In a cohort study of Arrow et al. (2011), the occlusal status appeared to have limited association with

psychosocial factors (Arrow et al. 2011). Heravi et al. (2011) studied randomly selected young males and found that malocclusion was significantly associated with poorer OHRQoL, but only with the oral symptoms dimension of OHRQoL, and not with functional limitations, emotional well-being or social wellbeing (Heravi et al. 2011). In a review Kiyak (2008) concluded that patients focus primarily on aesthetic and social aspects of OHRQoL as a motive for seeking orthodontic treatment (Kiyak 2008). The type of malocclusion did not affect patients' OHRQoL as much as its severity or visibility (Silvola et al. 2012). In general, the impact of self-perceived malocclusion primarily affected psychological and social everyday activities such as smiling, emotion, and social contact (Bernabe et al. 2009; O'Brien et al. 2007b).

There are some studies which examined the association of specific malocclusion traits with OHRQoL. Traebert and Peres (2005) found that incisal crowding, anterior maxillary irregularity and large overjet had an impact on OHRQoL, especially in terms of satisfaction with appearance, while the molar relationship did not have an impact (Traebert and Peres 2005). A study of college students supports these findings; individuals with incisor crowding and anterior maxillary irregularity greater than two mm were at least twice as likely to experience an impact on "smiling, laughing, and showing teeth without embarrassment." Further, individuals with overjet greater than five mm were almost four times more likely to experience impacts on their emotional state (Traebert and Peres 2007).

2.9 Models of oral health, oral health and malocclusion

Most HRQoL instruments, are based on the World Health Organization's International classification of Impairments, Disabilities and Handicaps (ICIDH, also known as ICIDH-1) (WHO 1980); ii) International Classification of Functioning, Disability and Health (ICF, also known as ICIDH-2) (WHO 1998) . These classifications proposed a theoretical explanation of the consequences of diseases or health disorders by defining and integrating the concepts of impairment, disability and handicap. Impairment is an immediate anatomical or physiological outcome (loss or abnormality) of disease. Functional limitations, pain and discomfort refer to the functioning and psychological well-being. Disability and handicap refer to any difficulty in performing activities of daily living and to the broader social disadvantages for a given individual that limits or prevents the fulfilment of a role that is normal for that individual. Impairment is commonly assessed by clinical indicators, whereas rest others are assessed through self-report procedures (WHO 1998).

As an aid to assessing OHRQoL, it is acknowledged that there is a need to have a conceptual basis for OHRQoL. Numerous theoretical models have been proposed to link and elaborate the relationships among different domains and hierarchies of health, OHRQoL and clinical

variables. Among them two models, in particular, have been proved as useful in mapping out how to assess OHRQoL (Liu 2009). The most commonly used conceptual model in health that reflects these paradigm of health has been described by Wilson and Cleary (Wilson and Cleary 1995). This model, encompasses both biological and physiological variables at one end, and overall quality of life at the other end. In this model, symptoms of disease/disorder, functional, psychological, and social experiences related to that disease/disorder serve as a link between the two ends. More importantly, this model identifies the moderating role that the personal and environmental characteristics have on this causal sequence. Thus specified, the Wilson-Cleary model makes explicit the causal relationships between disease, health status, and HRQoL, while still acknowledging the holistic nature of QoL. There is considerable evidence of the usefulness of this model in outcome assessment in dentistry (Agou 2009; Williams et al. 1998).

However, the most common conceptual model used in oral health is Locker's conceptual model of oral health. Based on these classifications, Locker (1988) published a conceptual model to explain the consequences of oral health (Locker 1988). This model states that there are five consequences of oral disease: impairment, functional limitation, pain/discomfort, disability, and handicap (Mtaya 2008). Further the model proposes that these domains are sequentially related as shown in the Figure 1. According to this model, Impairment (structural abnormality e.g. malocclusion) leads to functional limitation (restrictions in body functions, e.g., difficulty chewing) and pain/discomfort (self-reported physical and psychological symptoms), which, in turn, leads to disability (limitations in performing daily activities, such as an unsatisfactory diet) and disability may then lead to handicap (social disadvantage, such as social isolation) (Baker 2007). Impairment and functional limitation may also lead directly to handicap. Thereafter, several indices based on the model have been developed to measure OHRQoL. Since then, much of the research, including research on malocclusion or orthodontic treatment and OHRQoL, has been based implicitly on this model (Locker 1988). This model has proved useful in the development of numerous OHRQoL measures (Locker and Allen 2007; Silvola 2014a). The positive levels of functioning are functional/structural integrity, activity and participation.

Locker's model has typically been viewed as a framework rather than as a scientific model to be empirically validated (Nuttall et al. 2006). However, to date it has not been determined whether, for malocclusion patients, the constructs in Locker's model relate to one another as hypothesized. There are several reasons why the model may differ in this patient group. First, malocclusion and orthodontic treatments differ from the majority of oral and dental diseases or conditions and interventions, in that malocclusion is 'a set of dental deviations' rather than a disease and orthodontic treatment does not cure a condition; but rather corrects variations

from an arbitrary norm (O'Brien et al. 2007a). Further, it has been suggested that the majority of oral health measures developed in dentistry are not applicable to orthodontic patients because most malocclusions are asymptomatic and related to aesthetics, as opposed to features of other diseases (O'Brien et al. 2007a; Rusanen et al. 2010). Therefore, it can be hypothesized that the pathways in Locker's conceptual model are not applicable to malocclusion patients in the manner suggested for other oral diseases and that, as a consequence, it is important to test and modify the model that can more appropriately show the consequences of malocclusion,

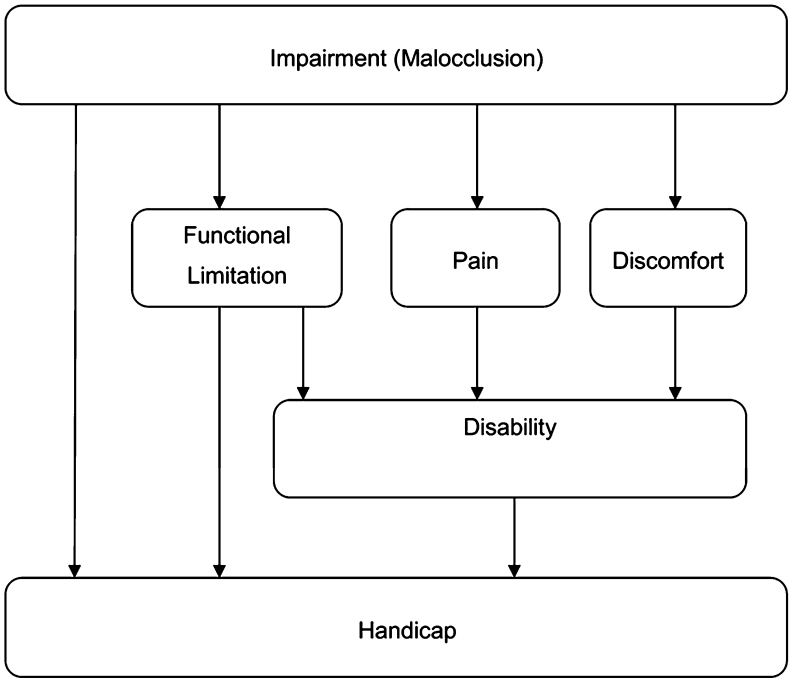

Figure 1: Locker's Conceptual Model of Oral Health (Locker 1988).

2.10 Measures of OHRQoL

In recent years, a large number of oral health specific quality of life measures have been developed and designed. Some are generic measure such as Oral Health Impact Profile (OHIP) (Slade and Spencer 1994) and Oral impacts on Daily Performances (OIDP) (Adulyanon and Sheiham 1997) whereas others, such as Short Form Health Survey (SF-36), are condition specific (Lee et al. 2007). Generic measures are useful for comparisons of OHRQoL between different conditions; however, their meaning and significance have been questioned (Locker and Allen 2007). Condition-specific measures focus on the particular problems relevant to a

disease or disorder, making them more sensitive (Bernabe et al. 2008b), more acceptable to participants and, therefore, higher completion rates are more readily achievable. Their specific nature makes them more likely to respond to change (Sischo and Broder 2011).

Some measures are age specific, language specific, culture specific or disease specific. An example for language or culture specific measure is the United Kingdom Oral Health-related Quality of Life measure (McGrath and Bedi 2001). An example of age specific measure is Geriatric Oral Health Assessment Index (GOHAI) for adult population (Atchison and Dolan 1990). A number of measures have been designed to assess the impact of oral conditions on children (Jokovic et al. 2002; Patel et al. 2016). Child oral health-related quality of life is the most popular child Oral Health-related Quality of Life measure consisting of the Child Perception Questionnaire (CPQ); the Parental Perception Questionnaire and the Family Impact Scale (Jokovic et al. 2002). The Child Oral Quality of Life questionnaire includes the Parental Caregiver Perception Questionnaire, the Family Impact Scale, three Child Perception Questionnaires for children aged 6-7-, 8-10- and 11- to 14 years, and the Child Oral Impacts on Daily Performance (Child-OIDP) inventory. Recently, the Early Childhood Oral Health Impact Scale (ECOHIS) was developed to assess oral health impacts among preschool children aged 0-5 years and the impact of a child's oral condition on the family (Pahel et al. 2007).

Most of these measures such as OHIP, ODIP and The United Kingdom Oral Health-related Quality of Life measures (OHQoL-UK) were developed based on the theoretical framework of ICIDH (McGrath and Bedi 2001). By far, the most popular measure has been the Oral Health Impact Profile (OHIP) (Slade 1997a; Slade and Spencer 1994). Its development was based on the WHO's International Classification of Impairments, Disabilities and Handicaps (ICIDH) (WHO 1980). It consists of seven domains reflected in the ICIDH model: functional limitation; physical pain; psychological discomfort; physical disability; psychological disability; social disability and handicap. OHIP items were developed from open-ended interviews with 64 dental patients recruited from private practices and dental hospital clinics. From an initial item pool set of statements collected in the interviews, 46 unique items were selected based on their ability to represent the domains of ICIDH. Three additional items were added to represent the handicap domain. Thus, in its original, form OHIP consists of 49-items. Subsequently, a short form measure of OHIP was derived called OHIP-14 (Slade 1997a). This short form measure of OHIP was shown to have psychometric properties that were similar to the original 49-item version and being shorter to administer made it particularly popular (Slade 1997a). The psychometric properties of OHIP-14 have been tested in a wide variety of settings and adapted for use in other languages (John et al. 2002; Larsson et al. 2004; Saub et al. 2005).

Oral Health Impact Profile (OHIP) has been widely used due to its good psychometric properties. OHIP-14 is considered a more practical instrument in clinical practice and epidemiological surveys and has also shown good reliability and validity (Kragt et al. 2015). OHIP-14 was originally tested on adults over 60 years, but the measure has subsequently been suggested to have at least equal relevance in people under 60 years old (Nuttall et al. 2006). OHIP-14 has been used for a variety of oral diseases and conditions including malocclusion and orthodontic treatment (Lahti et al. 2008; Larsson et al. 2004). OHIP-14 has been validated for several cultures and languages including Malay and Finnish cultures and languages. It has been used in national surveys of UK, Australia, Malaysia, German and Finland (Slade et al. 2005). The Malaysian and Finnish version have been found to be valid and reliable (Lahti et al. 2008; Saub et al. 2005).

Initially, OHRQOL was evaluated in orthodontics using generic measures that were originally developed in the field of dentistry. It was argued that the majority of health or OHRQoL measures cannot be readily applied to orthodontic patients as they focus on pathological conditions, disease, pain and discomfort. It is widely accepted that orthodontics does not fit the conventional ‘health model’, as the majority of treatment is not related to disease and instead aims to correct a malocclusion against a perceived societal norm (O'Brien et al. 1998; Patel et al. 2016). But there is no appropriate malocclusion specific OHRQoL measures available. Therefore, several studies, using these generic measures of OHRQoL, have shown that malocclusion has an effect on the everyday life and activities of young people (Kok et al. 2004; O'Brien et al. 2007b). Adult instruments like the Oral Health Impact Profile (OHIP) and the Oral Impacts of Daily Performance (OIDP) have been used to assess the impacts of malocclusion (Slade and Spencer 1994; Slade 1997b). Foster Page et al., investigated the ability of the CPQ11-14 to discriminate between various levels of malocclusion severity and revealed that there was a statistically significant distinct gradient in mean CPQ11-14 score by malocclusion severity (Foster Page et al. 2008). Most measures developed to assess the OHRQoL, appear to be theory based and well tested for psychometric properties in terms of reliability and specific attributes of validity (i.e. content, construct and criterion validity) (Brondani and MacEntee 2007; Mtaya 2008).

The Psychosocial Impact of Dental Aesthetics Questionnaire (PIDAQ) (de Paula Junior et al. 2009) and the Orthognathic Quality of Life Questionnaire (OQOL) (Lee et al. 2008) and children Oral Aesthetic Subjective Impact Scale (OASIS) were developed more recently for assessment of orthodontic and orthognathic aspects of the quality of life (Guyatt et al. 1993; Klages et al. 2006). Although these measures were developed for orthodontics related problems, they have some disadvantages. The PIDAQ considers only the aesthetic aspects of

the malocclusion and misses the functional aspects. The Orthognathic Quality of Life Questionnaire (OQLQ) has been developed specifically for orthodontic-surgical patients. OQLQ has been designed to evaluate orthodontic-surgical patients only, which limits its use in orthodontic patients (Cunningham et al. 2002). However, OASIS was originally designed to reflect orthodontic treatment need, and it has not been so far applied as an outcome measure. It seems that the developers have given little consideration to the multidimensional aspect of OHRQoL. Further, its technical properties are not known as it was not tested in different groups. Thus, it is fair to conclude that at present, there is no specific comprehensive OHRQoL measure available that could be potentially useful in the context of people with malocclusion and OHIP-14 is the most commonly used measure available at present to measure the impact of malocclusion on OHRQoL (Agou 2009; Allen et al. 1999).

2.11 Clear statement of the problem

Overall, little emphasis has been given to OHRQoL outcomes in orthodontics. Recent years researchers in the field of orthodontic have emphasized that the measurement of patient-based outcomes is essential to measure orthodontic treatment need and measure the effectiveness of orthodontic treatment (Agou 2009; de Oliveira and Sheiham 2003). There has been a considerable amount of interest in establishing the relationship between malocclusion or orthodontics treatment and the quality of life. However, there is a lack of consensus about their relationship and there are some important aspects that need to be explored to clearly understand the relationship between malocclusion or orthodontics treatment and the quality of life.

First, there is minimal evidence available to suggest the relationship between various domains of the quality of life (such as functional limitation, psychological discomfort etc.) and malocclusion. Greater research is required to understand the physical, social, and psychological impact of malocclusion on OHRQoL and its individual domains and their interrelationship. This is necessary because this sheds light on the effects of malocclusion on people’s lives and provides more understanding of the demand for orthodontic treatment beyond clinician parameters.

Secondly, most of the available literature uses malocclusion as a whole identity to measure its impact on the quality of life. However, it is also important to look at the relationship of individual malocclusion traits (such as cross-bite, overjet, overbite etc.) on the quality of life. It will give a more specific understanding of the malocclusion and its impact on the quality of life. This is again important in prioritizing the need for orthodontic service.

Third, it is important to assess the effect of malocclusion on the quality of life of the children or adolescents, as they are the major utilizers of the orthodontic services. Additionally, it is also important to assess the impact of malocclusion on the quality of life of the adults in the population. For most part, the assessment of malocclusion and orthodontic treatment need have been conducted among children rather the adults. In recent times, there has been a considerable interest in adult orthodontics with increasing number of adults seeking orthodontic treatment. Because of biological and physiological features, as well as social and psychological attributes, special attention needs to be paid to managing the needs of adult population (Liu 2009). Determining this will help in prioritizing the orthodontic treatment for adults.

Fourth, research direction on malocclusion and OHRQoL was, however, limited by the lack of theoretical oral health models for malocclusion. A theoretical model is required to demonstrate how the different aspects of quality of life are related to malocclusion and to operationalize the concept of malocclusion. A specific model is also required to develop malocclusion specific OHRQoL measure (Agou 2009). Models to explain the consequences of a disease are typically developed from a theoretical basis. Ideally, once the theoretical basis has been established, a model should be tested in a population and suitably refined (Nuttall et al. 2006). The use of a malocclusion-specific quality of life model will allow clinicians and health policymakers to better understand the effects of malocclusion, and its treatment, on people over time (Patel et al. 2016). Developing knowledge of key pathways will help facilitate the design of intervention strategies, by, for example; guiding clinicians as to where and how to intervene most effectively in patients with malocclusion (Baker et al. 2008). It is hoped that this, in turn, will lead to the provision of an enhanced quality of care.

3 AIMS OF THE STUDY

The aim of this study was to determine the association between malocclusion and oral health-related quality of life (OHRQoL).

The specific objectives were

1. Association of malocclusion on oral health related quality of life in young people.
2. Malocclusion traits and Oral Health Related Quality of Life in adult population.
3. Testing and modification of the conceptual model of oral health for malocclusion patients.

4 MATERIALS AND METHODS

4.1 Subjects

This thesis is based on four different papers (I-IV). Two different datasets were used in these four papers. Paper I, II and IV were conducted in Malaysia and study II was conducted in Finland. For paper I, II and IV, a dataset from Malaysia was used throughout this thesis. The Malaysian dataset is referred to as “Malaysian Dataset”. For study II, national Health 2000 Survey data from Finland was used. Throughout this thesis, this dataset is referred to as “Finnish Dataset”.

4.2 Study Design

4.2.1 Malaysian Dataset (I, II, IV)

Patients attending orthodontic clinics at the Faculty of Dentistry, Universiti Teknologi MARA, Malaysia were asked to participate in this study. The participants or their parents signed an informed consent form, and agreed to participate in the study. Participants were either motivated by their parents or self-motivated to seek orthodontic consultation rather than being referred from other orthodontic clinics. A convenience consecutive sampling approach was used, wherein any patients who agreed to participate in this study and fitted the exclusion inclusion criteria was included in the study. Participants in the study were aged between 15 and 25 years. To be included in this study, the participant had to be in good general health with no known systemic disease such as diabetes. Participants warranting surgical intervention or those who had chronic medical conditions, previous orthodontic treatment, severe dentofacial anomalies such as cleft lip and palate, untreated dental caries, and poor periodontal health status as indicated by a community periodontal index score of 3 or more were excluded. This was to prevent possible confounding effects of these conditions on the participants’ quality of life and to achieve a homogeneous group population.

The participants were recruited at their first visit for orthodontic screening before starting any orthodontic treatment. OHRQoL was assessed for all participants using OHIP-14 questionnaire before the orthodontic examination. All participants completed the OHIP-14 without any help or assistance from parents or guardians. After assessing OHRQoL, and before any orthodontic treatment, a comprehensive clinical examination was done to measure orthodontic treatment

need using IOTN-DHC. All these procedures were done in orthodontic clinics at the Faculty of Dentistry, Universiti Teknologi MARA, in Malaysia.

4.2.1.1 Examiners reliability tests

The IOTN-DHC ratings were recorded by two trained and calibrated examiners. To assess intra- and inter-examiner reliability, 20 subjects who were not part of the present study were randomly selected and re-examined at a 2 to 4-week interval after their first examinations. Intra-examiner reliability for the IOTN-DHC examiners was almost perfect with kappa= 0.91 and 0.96. Excellent agreement was found for the inter-examiner reliability with Kappa= 0.85.

4.2.1.2 Ethics approval

The study was approved by the Universiti Teknologi MARA (UiTM) Research Ethics Board, Shah Alam, Malaysia. The participants or their parents signed an informed consent form, and agreed to participate in the study. All data was kept confident.

4.2.2 Health-2000 survey (III)

Part of the data from the national Health 2000 Survey, Finland was used in study III. national Health 2000 Survey was a comprehensive nationwide survey, carried out in 2000–2001 by the National Institute for Health and Welfare (THL, previously the National Public Health Institute (KTL)) (Suominen-Taipale et al. 2008). A two-stage stratified cluster sampling method was used in this survey to select the participants. The main part of the survey comprised adults ≥30 year of age living in mainland Finland. This frame was regionally stratified according to the five university hospital regions, each containing approximately one-million inhabitants. From each region, 16 healthcare districts were sampled as clusters. Thus, the 80 health centre districts were the primary sampling units. The ultimate sampling units were subjects selected by systematic sampling from the health centre districts. Detailed information on sampling and methods of data collection has been published previously (Suominen-Taipale et al. 2008).

Data collection was carried out using structured health interviews, self-administered questionnaires, and comprehensive clinical health examinations. Subjects were first interviewed at home by Statistics Finland professional interviewers. On completion of the interview, a questionnaire was handed to each interviewee to be filled in at home and returned at the clinical examination, which took place, on average, one month later. The interviews and questionnaires were in both of Finland's official languages (Finnish and Swedish). The original forms and their English translations are available on the Internet pages of the survey

(http://www.terveys2000.fi/forms.html). A total of 8028 people were included in the sample representing those aged ≥30 year. The data for the article III was obtained from those participants who returned a self-administered postal questionnaire including the OHIP-14 and took part in the clinical oral examination (n=4711). The outcome variable was OHRQoL which was measured using the 14-item Oral Health Impact Profile (OHIP-14).

4.2.2.1 Ethics Approval

Permission for the survey was given by the ethics committees of the University Hospital Region of Helsinki and Surroundings and The National Public Health Institute. Written consent was taken from each participant before data collection. During the interview, the respondents received an information leaflet and their written informed consent was obtained.

4.3 OHRQoL (OHIP-14) (I-IV)

The outcome variable in all the studies (I-IV) was OHRQoL. OHRQoL was measured using translated version (Malay and Finnish language) of the 14-item Oral Health Impact Profile (OHIP-14). It has been shown that OHIP-14 has good reliability, validity, and precision (Allen et al. 1999; Slade 1997a). The Malay and Finnish version of OHIP-14 has also been found to be valid and reliable and has been used in nationally representative surveys to get population estimates for prevalence, extent, and severity (Saub et al. 2005). Finnish version of OHIP-14 questionnaire was pilot tested for feasibility and reliability after back-and-forth translation among adults aged 21–94 year (Lahti et al. 2008). Finnish version OHIP-14 was found to be reliable, the internal consistency being 0.93 (Crohnbach's alpha) (Lahti et al. 2008). The internal consistency of the subscales of the Malay version of OHIP-14 was calculated using Cronbach's alpha, the values of which varied from 0.70 to 0.90 for OHIP-14 subscales, demonstrating a good level of internal consistency for orthodontic patients. It was not deemed feasible to assess test-retest reliability of Malay version of OHIP-14, as this would assume that there was no change in oral health status between tests. As orthodontic treatment covers a period of months or years, there was a high likelihood of change in oral health status.

OHIP-14 assesses the burden of oral health status on life quality across seven conceptual domains (functional limitation, pain, psychological discomfort, physical disability, psychological disability, social disability and Handicap). Each domain contains two questions. Oral health-related quality of life was measured by asking subjects to rate the frequency of occurrence of a particular problem as captured by the individual item. Responses are rated on a 5-point Likert scale: 0 = never; 1 = hardly ever; 2 = occasionally; 3 = fairly often; 4 = very often/every day.

Summary OHIP-14 scores range from 0 to 56. These scores are calculated by summing ordinal values for 14 items. The summary scores for each domain range from 0 to 8. Higher OHIP-14 scores indicate worse and lower scores indicate better oral health-related quality of life. All participants completed the OHIP-14 questionnaire before any orthodontic treatment.

4.4 Clinical examination

4.4.1 IOTN (I and IV)

In Malaysian dataset (I and IV), after participants were interviewed using OHIP-14, clinical examinations were conducted to assess normative orthodontic treatment need using Dental Health Component (DHC) of the Index of Orthodontic Treatment Need (IOTN). This index has gained international acceptance because it is valid, reliable and easy to use (Jarvinen 2001). For the Dental Health Component (DHC) of IOTN, 10 traits of malocclusion are assessed: overjet, reverse overjet, overbite, openbite, crossbite, crowding, impeded eruption, defects of cleft lip and palate as well as any craniofacial anomaly, Class II and Class III buccal occlusions, and hypodontia. Only the highest scoring trait is used to assess the treatment need (Brook and Shaw 1989). Treatment needs of the patients were categorized as Grade 1 or no treatment need, Grade 2 or little treatment need, Grade 3 or borderline need, and Grade 4 and 5 or high treatment need (Brook and Shaw 1989) need.

4.4.2 Malocclusion Traits (II and III)

4.4.2.1 Cross-bite (II)

A subset of the data from the Malaysian dataset was used in this study to measure the effect of cross-bite on OHRQoL. Posterior cross-bite was diagnosed when an inverted relationship of occlusion was observed between at least 1 posterior tooth in the transverse plane. Patients who had a cross-bite by this definition were classified as cases for this study and patients who were detected negative for cross-bite and other malocclusal traits (such as overjet, reverse overjet, overbite, open-bite, crowding, impeded eruption, defects of cleft lip and palate as well as any craniofacial anomaly, Class II and Class III buccal occlusions, and hypodontia) were classified as controls.

4.4.2.2 Malocclusal Traits (III)

In Finnish dataset (III), three malocclusion traits; occurrence of overjet, cross-bite/scissor-bite and over-bite/open-bite were used as explanatory variables. Overjet variable was registered as four categories 0=0-6mm, 1=7-9mm, 2=<0mm, 3=>9mm; it was dichotomised as overjet present for

the categories 1,2 and 3 and absent for the category 0. Cross-bite variable was registered as 0=No, 1=cross bite, 2=Scissor bite, 3=both; it was dichotomised with cross-bite or Scissors bite or both were coded as present and rest as absent. Overbite variable was registered as 0=normal, 1=cervical one-third, 2=open bite, 3=traumatic bite; it was dichotomised with traumatic bite or open bite as 1 (present) and rest 0 (absent).

For the examination of occlusion, entries were made on the number of opposing teeth, cross-bite, scissors bite, open bite, deep bite, overjet and the intercuspal relationship (Angle's classification). Neither missing teeth nor teeth in removable dentures were taken into account. Wisdom teeth were also not taken into account. Cross-bite and scissors bite were both recorded in one of two categories. Cross-bite was determined for both frontal and lateral teeth and was recorded when a maxillary tooth came inside the opposing mandibular tooth, i.e. on the lingual side. Scissors bite was determined for side teeth and was recorded when a maxillary tooth overlapped the opposing mandibular tooth without any contact between the occlusal surfaces. Open bite was measured from the central incisor in the upper right quadrant and in its absence from the corresponding tooth in the upper left quadrant. Measurements were taken from teeth in occlusion using a WHO periodontal probe with a ball end (Plandent Oyj, no. 19577). Overjet was measured as the distance between the incisal tip of the upper incisor and the anterior surface of the lower incisor. Overbite was determined according to the position of the tip of the lower incisor in relation to the upper incisor when biting the teeth together. The sagittal relation between the upper and lower jaw was determined using a modification of Angle's classification as normal; upper canine clearly distally from lower canine; upper canine clearly anteriorly from lower canine; and upper and lower canine in a cusp to cusp relationship.

4.5 Covariates

In the Malaysian dataset, data was collected for gender, age group and educational background because of their potential associations with both outcome and explanatory variables. For the Finnish dataset, the data for gender, age group, marital status, education level, equivalized income quintiles, employment status was collected through interview or questionnaire. Data on the oral health status was measured as having at least one decayed tooth (absent/present), at least one periodontal pocket ≥6mm (absent/present), ever received orthodontic treatment (absent/present). Number of contacting pair of teeth was divided into six categories (0, 1–8, 9–16, 17–20, 21–24 and 25–32 teeth). Denture status (wearing either partial or full removable dentures) was dichotomised as yes or no. Self-reported general health status was measured as

good (good or rather good), moderate, or poor (rather poor or poor). These variables were used as confounding variables in the analysis.

4.6 Statistical analysis

The data was analysed by using R-Project software and AMOS software (Team 2012). Additive scale for OHIP-14 was calculated by summing all the item response codes. Additive subscales for each domain of OHIP-14 were calculated by summing both the items response codes of that domain. Data analyses included descriptive statistics using mean standard deviation and frequency with percentage. Group comparison was done using chi-squared test for, student's t-test, One-way ANOVA with Tukey Post Hoc. Bivariable and multivariable linear regression analysis were used to measure the association between OHRQoL and IOTN-DHC, sex, age and education level in article I. OHIP-14 scores were used as continuous outcome variable in linear regression analysis. Bivariable linear regression models were performed individually separately with each explanatory variable. All the explanatory variables were recoded for modelling purposes. IOTN-DHC was recoded as No treatment required=0, little treatment required=1, borderline treatment required=2 and high treatment required=3.Gender was recoded as Male=0 and Female=1. Age groups was recoded as 15-18 years=0, 19-21 years=1, 22-25 years=2. Educational level was recoded as secondary education=0 and university education=1. Finally, all the explanatory variables were combined into a multivariable linear regression model to assess the relationship of IOTN-DHC on OHRQoL after controlling for covariates.

Bivariable and multivariable linear regression analysis were also used to measure the association between OHRQoL and cross-bite. In this analysis, OHIP-14 scores were also used as a continuous outcome variable. Cross-bite was recoded as No=0, yes=1, other variables gender, age groups and educational level were categorised as in paper I. Additionally, multivariable linear regression modelling was done to predict the impact of lower order domains of OHIP-14 (Functional limitation, pain and discomfort) on higher order domains of OHIP-14 (Physical disability, psychological disability, social disability and handicap) after adjusting for cross-bite, age, gender and education level. Separate models for each higher domain were used, with higher domains as outcome variables and all lower domains as predictors along with cross-bite, age, sex, education level and cross bite.

National Health 2000 Survey data was collected using complex survey design. Therefore, "survey" and "pscl" packages of R-project statistical software were used to take account of

complex survey features. Survey package in R uses design features (stratification, clustering and unequal probability of selection) to provide country level estimates. In this data, scores for total OHIP-14 and its domains were continuous count variables with a high prevalence of zero values. Therefore, a series of sequential multi-variable Zero Inflated Poisson (ZIP) models were used to estimate the associations between explanatory variables and OHIP-14. ZIP model provides incidence rate ratios (IRR) for the non-zero scores and odds ratios (OR) of having no event i.e. score of zero in the outcome. Simple Poisson regression was also run, the Vuong test was used to compare simple Poisson regression model and ZIP models, indicating that the zero-inflated models were superior. Multicollinearity was checked for all the malocclusion traits and confounding variables using variance inflation factor (VIF) scores. VIF score was lower than 2.5 cut-off value for all the malocclusion trait variables. It was higher than the cut-off value for marital status, income and employment status. Since the multicollinearity of confounding factors does not affect the standard error of the variables of interest, this multicollinearity was ignored (Allison 1999).

Covariates were categorised as follows, age group was categorized into three groups (0=30–44, 1=45–54, 2=55+ year); marital status was categorised as 0= Single, 1= married/living with partner and 2=Divorced/widowed/living apart. Information on level of education was categorized into three classes: 0=basic, 1=secondary, and 2=higher. For income, equivalized income quintiles were used after adjusting for the household size (OECD 2015). Employment status was categorised into five categories; 0=full time employed, 1=part-time employed, 2=unemployed, 3=retired and 4=others. Oral health status was measured as having at least one decayed tooth (0=absent and 1=present), at least one periodontal pocket ≥6mm (0=absent and 1=present), ever received orthodontic treatment (0=absent and 1=present). Number of contacting pair of teeth was divided into six categories (0=0 pair of teeth, 1=1–8 pair of teeth, 2=9–16 pair of teeth, 3=17–20 pair of teeth, 4=21–24 pair of teeth and 5=25–32 t pair of teeth). Denture status (wearing either partial or full removable dentures) was dichotomised as 0=no or 1=yes. Self-reported general health status was measured as 0=good (good or rather good), 1=moderate, or 2=poor (rather poor or poor). These variables were used as confounding variables in the analysis.

SEM with path analysis with AMOS 20.0(Arbuckle 2011) was used to test and modify OHRQoL conceptual model for the malocclusion data. This method evaluates the relative importance of different paths between the variables, and also estimates the direct effects (a path directly from one variable to another, e.g., functional limitations → disability) and indirect effects (a path

mediated through other variables, e.g., functional limitations → handicap via disability). The strength of direct and indirect effects for different paths was measured by β-coefficients with standard deviation. Three models (a basic model, a modified model and the final model) were developed to test different possible paths for each domain from malocclusion to handicap. In the basic model, all the paths, as hypothesised by Locker's model, were analyzed. Modification index was used to modify the basic model and all the paths suggested by the modification index were relaxed. To develop the final model, all the non-significant paths were removed from the modified model. Maximum likelihood (ML) estimation and boot- strapping methods were used to calculate regression parameters. Direct, indirect effects and the total effects were estimated, total effects are made up of both the direct and indirect effects. The bootstrap methods have been advocated as the best approach to testing direct and indirect effects in mediation models (Baker 2007; Baker et al. 2007; Baker et al. 2008). 1000 bootstrap samples were created in order to derive less biased standard errors and 95% confidence interval (CI) bootstrap percentiles (Shrout and Bolger 2002). These Biased corrected or bootstrapped standard error and confidence intervals have been shown to be more accurate for calculating indirect effects (Baker 2007). We also assessed whether mediation was present by testing the significance of the indirect effect using the bias corrected bootstrap confidence intervals. To assess the fit of the models, several indices such as Chi-square value, Goodness-of-fit index (GFI), Adjusted Goodness-of-fit (AGFI), Comparative fit index, Root mean square error of approximation (RMSEA), Normalised Chi-squared value and p-value were generated and compared.

5 RESULTS

A synthesis of the results is reported without following the order of the original articles. Roman numerals refer to the original articles. The results are presented according to the aims of the study, which were 1) to measure the Impact of malocclusion on oral health related quality of life [Paper I], 2) to measure the relationship of various malocclusion traits and oral health related quality of life [Papers II and IV], and 3) to test and modify the conceptual model of oral health related quality of life for malocclusion patients [Paper III].

5.1 Malocclusion and OHRQoL [Paper I]

A total of three hundred and twenty-five participants were included in paper I to test the association of malocclusion and OHRQoL. This paper included participants from Malaysia. Normative treatment need according to IOTN-DHC was present in 252 (78.0%) participants, the remaining 71 participants (22%) did not have any normative treatment need for orthodontic treatment (Table 3).

Table 3: Characteristics of the participants included in paper I. (n=323)

		n(%)
Gender		
	Male	130(40.2)
	Female	193(59.8)
Education		
	Secondary education	48(14.9)
	University education	275(85.1)
IOTN		
	No treatment need	71(22.0)
	Little treatment need	87(26.9)
	Borderline treatment need	80(24.8)
	High treatment need	85(26.3)

Mean OHIP-14 score gradually increased with the severity of malocclusion; people with little orthodontic treatment need had significantly higher OHIP-14 score compared to people with no treatment need. People with high treatment need had significantly higher OHIP-14 score than other IOTN categories (Figure 2).

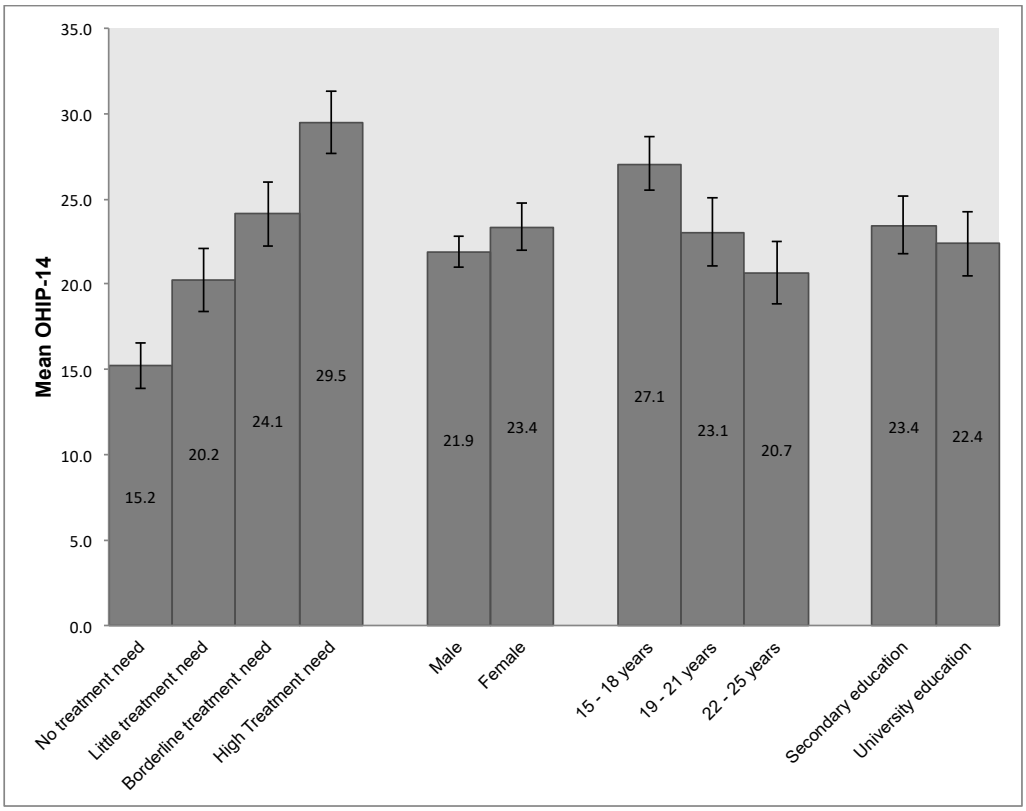

Figure 2: Mean OHIP-14 scores in 323 patients according to IOTN, gender, age group and education level.

People with high treatment need reported a significantly more negative impact on each domain of OHIP-14 (Table 4). The greatest impact was seen in the psychological discomfort domain where even having little treatment need had significantly different OHIP-14 scores compared to the reference group " No treatment need". Whereas, the other domains i.e. functional limitation, physical pain, physical disability, psychological disability and social disability showed significant difference in OHIP-14 scores at borderline treatment need group. Handicap domain showed significantly different OHIP-14 scores only for the high treatment need group.

Table 4: Mean scores in overall and seven domains of Oral Health Impact Profile-14 (OHIP-14) OHIP-14 among different types of Index of Orthodontic Treatment Need- Dental Health Component (IOTN-DHC) groups.

IOTN	n (%)	Functional limitation	Physical pain	Psychological discomfort	Physical disability	Psychological disability	Social disability	Handicap
No treatment need	71 (22.0%)	2.2±1.8	2.1±1.6	2.6±1.8	2.0±1.6	2.0±1.6	1.8±1.6	2.4±1.7
Little treatment need	87 (26.9%)	3.2±1.9	3.0±1.6	3.8±1.8***	3.0±1.9	2.0±1.6	2.2±2.0	2.9±1.8
Borderline treatment need	80 (24.8%)	3.9±2.0**	3.4±1.3**	4.5±1.6***	3.4±1.9*	2.9±1.7*	2.9±1.9*	3.2±1.9
High Treatment need	85 (26.3%)	4.8±2.0***	4.2±1.7***	4.9±1.7***	4.0±2.0***	3.6±1.9***	3.8±2.2***	4.1±2.0**
All participants	232 (100%)	3.6±2.1	3.3±1.7	4.0±1.9	3.2±2.0	2.6±1.8	2.7±2.1	3.2±2.0

* P<0.05, ** P<0.01 and ***P<0.001

Group comparison and P-values calculation was done using One Way ANOVA and Tukey Post Hoc test

The multivariable regression analyses show a significant association of normative orthodontic treatment need with overall OHIP-14 scores after controlling for other covariates gender, age group and education level (Table 5). People with high treatment need had 14 points higher score of OHIP-14 than people with no treatment need. The final multivariable model explained 22% variation in the total score of OHIP-14 (R^2 =0.22).

Table 5: Multivariable linear regression models showing association of Oral Health Impact Profile-14 (OHIP-14) with Index of Orthodontic Treatment Need- Dental Health Component (IOTN-DHC) and other covariates.

	Multivariable analysis	
	Estimates	SE
IOTN-DHC		
Intercept	15.239	1.37***
No treatment need	Reference Group	
Little treatment need	4.77	1.79**
Borderline treatment need	9.03	1.83***
High Treatment need	14.41	1.80***
Gender		
Male	Reference Group	
Female	1.36	1.28
Age group		
15 - 18 years		
19 - 21 years	-6.12	2.22**
22 - 25 years	-9.46	2.12***
Education Level		
Secondary education	Reference Group	
University education	4.45	2.24*
	R^2=0.22	

* P<0.05, ** P<0.01 and ***P<0.001

5.2 Malocclusion Traits and OHRQoL [Paper II and IV]

To examine the effect of malocclusion traits on OHRQoL, two different datasets were used. First from clinical patients and second from Finland national Health 2000 Survey data. In paper II, a total of 145 respondents (72 patients with cross-bite and 73 control participants) were assessed. There was no significant difference in the case and control group in gender, age and education level (Table 6). The mean overall score (± SD) for OHIP-14 score in total and all domains were significantly higher in cross-bite patients as compared to control (Figure 3).

Table 6: Sociodemographic characteristics of cross bite patients and controls

Variable		Cross Bite (n=71)	Control Group (n=72)
Gender			
	Male	29	27
	Female	42	45
Age			
	15 - 18 years	7	10
	19 - 21 years	19	26
	22 - 25 years	45	36
Education level			
	Secondary education	6	11
	University education	65	61

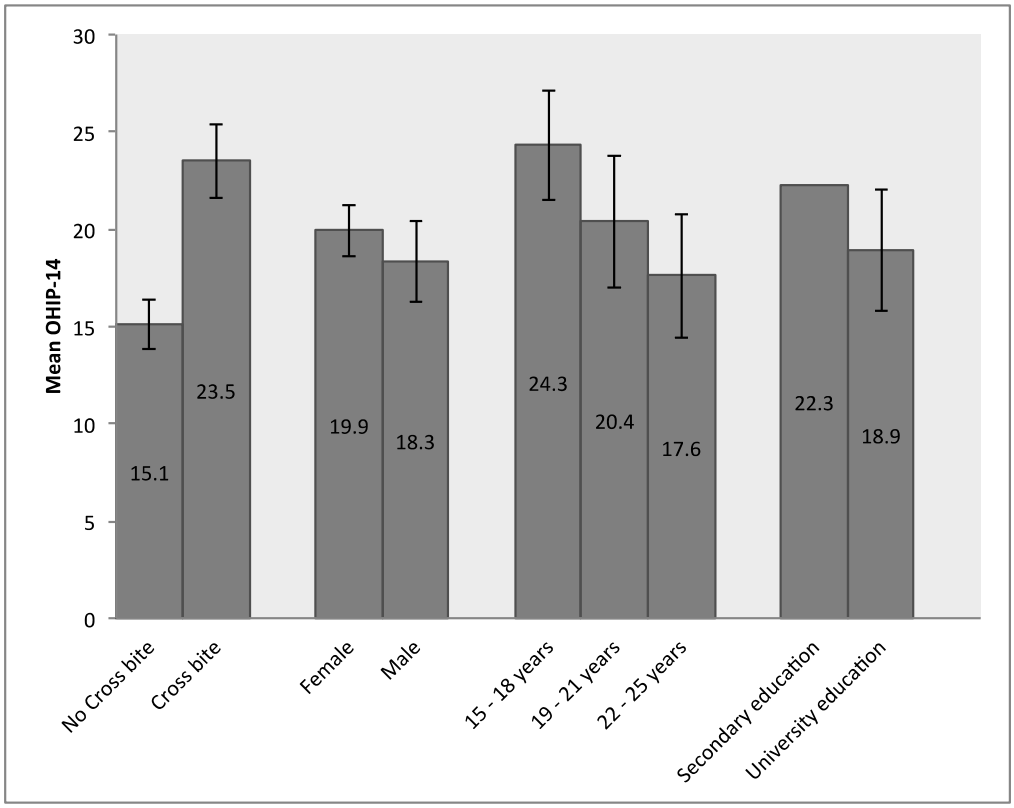

Figure 3: Mean OHIP-14 scores in 145 patients according to cross bite, gender, age group and education level.

Patients with cross-bite had significantly higher scores in all the seven domains of OHIP-14. Social disability domain of OHIP-14 showed least impact due to cross-bite. Whereas, psychological discomforts domain was the highest impacted domain (Table 7).

Table 7: Mean and standard deviation (SD) of Oral Health Impact Profile- 14 (OHIP-14) in cross-bite and no cross-bite groups

	Cross Bite (n=71)	No cross-bite Group (n=72)
OHIP-14 Domain	Mean±SD	Mean±SD
Functional limitation	3.89±1.95	2.18±1.86***
Physical pain	3.45±1.56	2.18±1.63***
Psychological discomfort	4.24±1.69	2.62±1.82***
Physical disability	3.14±2.02	2.04±1.61***
Psychological disability	2.86±1.75	1.97±1.69**
Social disability	2.85±2.06	1.81±1.68**
Handicap	3.11±2.07	2.33±1.77*

*Group comparison and P-values calculation was done using student's t-test.

The multivariable regression analyses show a significant association of cross-bite with overall OHIP-14 score. People with cross-bite have 9.2 points higher impact on OHIP-14 as compared to people with no cross-bite after controlling other covariates (Table 8).

Table 8: Multivariable linear regression models showing association of Oral Health Impact Profile-14 (OHIP-14) with Cross-bite and other covariates.

		Multivariable analysis	
		Estimates	SE
Cross Bite			
	Intercept	15.1	1.3
	No cross-bite	Reference Group	
	Cross bite	9.2	1.9***
Gender			
	Female	Reference Group	
	Male	-2.8	1.9
Age Groups			
	15 - 18 years	Reference Group	
	19 - 21 years	-4.7	4.4
	22 - 25 years	-9.1	4.3*
Education Level			
	Secondary education	Reference Group	
	University education	0.92	4.3
		R^2 = 0.16	

Table 9 shows multivariable regression analysis to identify the impact of lower domains of OHIP-14 on higher domains of OHIP-14 after adjusting cross-bite and other covariates. Functional limitation was significantly associated with physical disability, psychological disability, social disability and handicap domains, whereas pain was significantly associated only with psychological disability domain and discomfort was significantly associated only with physical disability domain (Table 9)

Table 9: Multivariable linear regression models showing prediction of impact in higher order domains of OHIP-14 (Physical disability, psychological disability, social disability and handicap) by lower order domains of OHIO-14 (Functional limitation, pain and discomfort).

	Outcome Variables			
	Physical Disability	Psychological disability	Social Disability	Handicap
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Intercept	0.15(0.35)	0.16(0.32)	0.59(0.48)	0.19(0.39)
Functional Limitation	0.53(0.09)***	0.35(0.09)***	0.57(0.11)***	0.63(0.10)***
Pain	0.03(0.13)	0.38(0.12)**	0.13(0.16)	0.07(0.14)
Psychological Discomfort	0.29(0.09)**	0.12(0.08)	0.05(0.11)	0.14(0.10)
R^2	0.70	0.71	0.56	0.64

Models were adjusted for gender, age group, education level and cross-bite

National Health 2000 Survey was also used to measure the effect of malocclusion traits on OHRQoL. Data from 4085 people was used in this analysis. Design based prevalence of overjet was 8.4% (n=317), cross-bite was 23.6% (n=990) and overbite was 6.7% (n=268) (Figure 4).

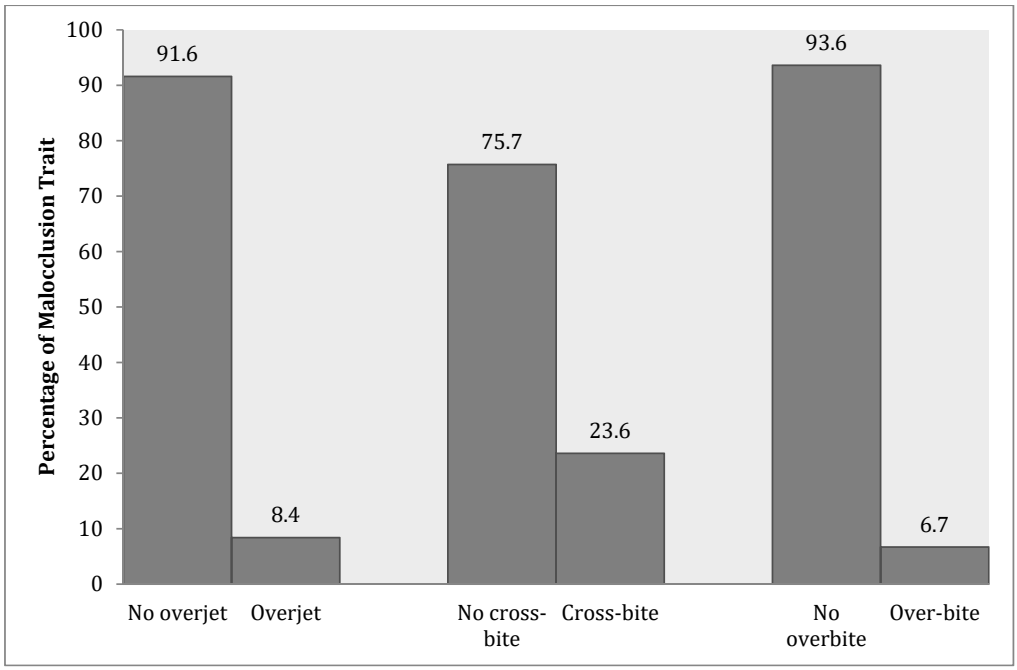

Figure 4: Prevalence of malocclusion traits (overjet, cross bite and over-bite) in Finnish adults.

OHIP-14 score was significantly higher in males, higher age, previously married, low education level, low income, full time employed, with active caries, with periodontal pocket, and lower number of contacting pair of teeth (Table 10). Mean (SE) OHIP-14 in overall sample was 2.85 (0.92). Total mean OHIP-14 score was significantly higher in people with overjet. However, it was not significantly higher in people with cross-bite or overbite (Figure 5).

Table 10: Designed based descriptive analysis of explanatory and confounding variables (n=4085).

	n(%)	Mean OHIP-14 (SE)
Sex		
Male	1855 (46.7)	2.91(0.13)*
Female	2230 (53.3)	2.68(0.11)
Age		
30-44	1892 (45.7)	2.64(0.14)*
45-54	1166 (27.7)	2.82(0.14)
55 and above	1027 (26.6)	3.00(0.17)
Marital Status		
Single	494 (12.2)	3.70(0.35)*
Married/living with partner	3060 (74.8)	2.46(0.09)
Divorced/widowed/living apart	531(13.0)	3.85(0.32)
Education		
Basic	1002 (24.9)	3.39(0.21)*
Secondary	1498 (36.3)	2.92(0.16)
Higher	1585 (38.8)	2.26(0.10)
Income		
1st quintile (Poorest)	752(18.2)	3.98(0.29)*
2nd quintile	949(24.0)	2.78(0.16)
3rd quintile	664(16.7)	2.67(0.19)
4th quintile	905(22.0)	2.54(0.18)
5th quintile (Wealthiest)	706(17.3)	2.02(0.12)
Missing values	109(2.8)	2.91(1.2)
Employment Status		
Full-time employed	753(18.3)	3.87(0.28)*
Part-time employed	1364(32.8)	2.59(0.14)
Retired	791(19.6)	2.42(0.21)
Unemployed	343(8.2)	2.28(0.24)
Others	834(21.1)	2.69(0.17)
At least one decayed tooth		
Absent	3004(72.1)	2.28(0.10)*
Present	1081(27.7)	4.17(0.24)
At leasy one Periodontal pocket ≥6mm		
Absent	3310(80.3)	2.66(0.10)*
Present	775(19.7)	3.30(0.20)
Denture		
Absent	3857(94.3)	2.62(0.09)*
Present	228(5.7)	5.64(0.41)
Self-perceived health		
Good	2954(73.2)	2.27(0.10)*
Moderate	867(20.4)	3.79(0.26)
Poor	264(6.4)	5.20(0.41)
Had orthodontic Treatment		
No	3592(87.7)	2.81(0.10)
Yes	493(12.3)	2.59(0.25)
Contacting paired teeth		
0-2 pairs	301(7.8)	6.19(0.50)*
3-4 pairs	426(10.5)	4.14(0.31)
5-6 pairs	786(19.2)	2.90(0.20)
7-8 pairs	2231(54.0)	2.16(0.11)
9-10 pairs	341(8.4)	1.88(0.26)

Unweighted frequency and design-based percentages are presented

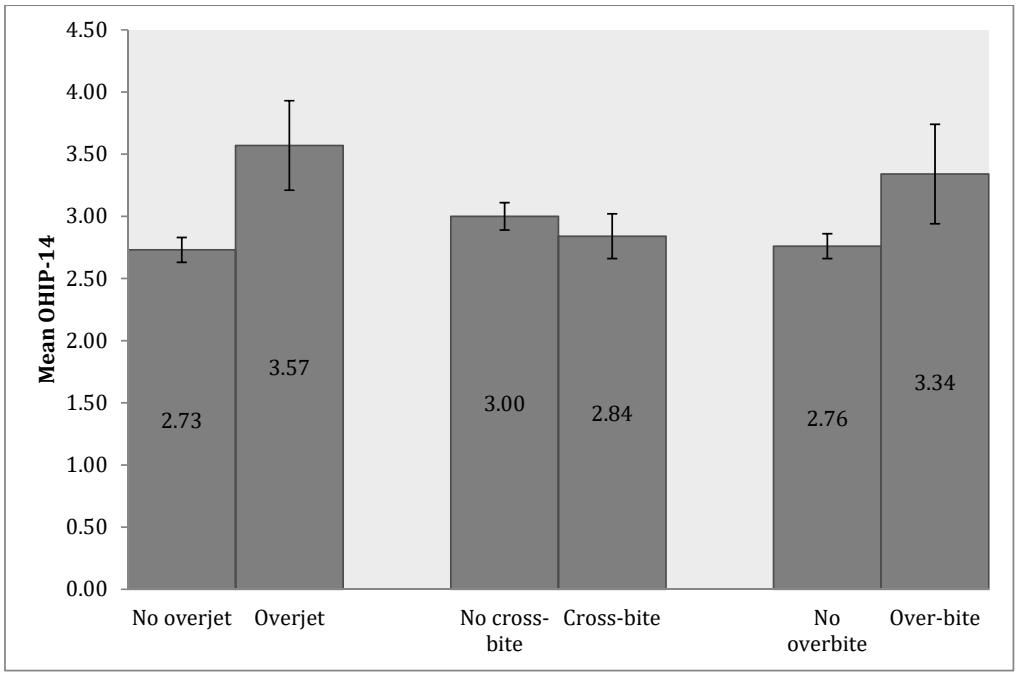

Figure 5: Mean total OHIP-14 scores in 4085 Finnish national Health 2000 Survey participants according to overjet, cross bite and over-bite.

Mean OHIP-14 scores in psychological discomfort, psychological disability and handicap domains were significantly higher in people with overjet. Mean scores for functional limitation, psychological discomfort and psychological disability were significantly higher in people with overbite compared with people without overbite.

Table 11: Design based distribution of OHIP-14 and its domains in overall sample and according to overjet, cross-bite and overbite.

	Overjet		Cross-bite		Over-bite	
	Absent	Present	Absent	Present	Absent	Present
	Mean(SE)	Mean(SE)	Mean(SE)	Mean(SE)	Mean(SE)	Mean(SE)
Functional Limitation	0.23(0.01)	0.31(0.06)	0.28(0.02)	0.24(0.03)	0.23(0.02)	0.30(0.06)*
Physical Pain	0.93(0.02)	1.09(0.08)	0.99(0.03)	0.93(0.04)	0.94(0.02)	0.99(0.09)
Psychological Discomfort	0.64(0.02)	0.91(0.09)*	0.71(0.03)	0.68(0.05)	0.65(0.02)	0.85(0.10)*
Physical Disability	0.19(0.01)	0.21(0.05)	0.21(0.02)	0.18(0.02)	0.18(0.01)	0.19(0.04)
Psychological Disability	0.32(0.02)	0.44(0.06)*	0.36(0.02)	0.34(0.03)	0.32(0.02)	0.46(0.07)*
Social disability	0.18(0.01)	0.25(0.05)	0.21(0.02)	0.21(0.03)	0.18(0.01)	0.22(0.05)
Handicap	0.25(0.01)	0.39(0.06)*	0.27(0.01)	0.29 0.03)	0.25(0.01)	0.35(0.06)

Design based Mann-Whitney U test was used to test the level of significance and to calculate p-value; *p-value ≤0.05

In bivariable zero-inflated Poisson regression models, overjet and overbite had a significant positive association with OHIP-14, but cross-bite had a significant negative association with OHIP-14 (Table 12). Multivariable ZIP model was adjusted for covariates. In this model, the association of overjet with OHIP-14 remains positive and significant after adjusting for covariates. People with overjet have 10% higher OHIP-14 score compared to people without overjet.

Table 12: Results of Multivariable design based Zero-inflated Poisson (ZIP) regression analysis to measure the effect of Overjet on OHIP-14.

	Bivariable		Multivariable	
	Poisson IRR(CI)	Zero-inflated OR(CI)	Poisson IRR(CI)	Zero-inflated OR(CI)
Overjet (Absent)				
Present	1.14(1.07; 1.21)*	0.73(0.58 0.92)*	1.09(1.01; 1.16)*	0.73(0.56; 0.96)*
Cross-bite (Absent)				
Present	0.94(0.90; 0.98)*	0.99(0.86; 1.14)	0.97(0.92; 1.01)	1.01(0.86;1.18)
Overbite (Absent)				
Present	1.18(1.10; 1.26)*	0.94(0.74; 1.20)*	1.00(0.92;1.08)	1.16(0.87;1.55)
Sex (Male)				
Female	-	-	1.09(1.04; 1.13)*	1.27(1.11; 1.46)*
Age (30-44)				
45-55	-	-	0.82(0.78; 0.86)*	1.09(0.91; 1.30)
55	-	-	0.65(0.61; 0.69)*	1.18(0.94; 1.47)
Marital Status (Single)				
Married/living together	-	-	0.86(0.80; 0.93)*	1.08(0.78; 124)
Widowed/divorced	-	-	1.02(0.95; 1.09)	1.03(0.78; 125)
Education (Low)				
Middle	-	-	1.01(0.96; 1.06)	0.93(0.77; 1.11)
High	-	-	0.95(0.89; 1.00)	0.85(0.69; 1.02)
Income (1st quintile)				
2nd quintile	-	-	0.84(0.79; 0.89)*	1.03(0.83; 1.27)
3rd quintile	-	-	0.98(0.92; 1.04)	1.13(0.89; 1.4)
4th quintile	-	-	0.89(0.84; 0.95)*	1.06(0.85;1.32)
5th quintile (Wealthiest)	-	-	0.84(0.78; 0.91)*	1.15(0.88;1.48)
Employment Status (Full-time employed)				
Part-time employed	-	-	0.86(0.80; 0.92)*	1.06(0.78;1.41)
Retired	-	-	0.88(0.80; 0.96)*	0.95(0.67;1.32)
Unemployed	-	-	0.81(0.72; 0.91)*	0.98(0.65;1.46)
Others	-	-	0.90(0.83; 0.98)*	1.02(0.74;1.39)
Denture (No)				
Yes	-	-	0.96(0.89; 1.03)	0.38(0.25;0.55)
Self-perceived health (Good)				
Mediocre	-	-	1.21(1.16; 1.27)*	0.64(0.54;0.76)*
Poor	-	-	1.43(1.24; 1.53)*	0.50(0.37;0.66)*
Had orthodontic Treatment (No)				
Yes	-	-	0.96(0.90;1.03)	0.99(0.80;1.21)

All models adjusted for having an active dental decay, periodontal disease, contacting paired teeth.

For OHIP-14 domains, overjet was associated only with physical disability domain, where people with overjet had higher physical disability compared to people without overjet. Cross-bite was associated only with the social disability domain, where people with cross-bite had lower social disability compared to people without cross-bite. Overbite was associated with psychological disability, where people with overbite had significantly higher psychological disability compared to people without overbite.

Table 13: Multivariable design based Zero-inflated Poisson (ZIP) regression analysis to measure the effect of overjet, cross-bite and overbite on OHIP-14 domains.

	Overjet		Cross-bite		Over-bite	
	Poisson	Zero-inflated	Poisson	Zero-inflated	Poisson	Zero-inflated
	IRR(CI)	OR(CI)	IRR(CI)	OR(CI)	IRR(CI)	OR(CI)
Functional Limitation	1.22(0.92;1.60)	1.04(0.67;1.61)	0.99(0.81;1.22)	1.08(0.81;1.44)	0.90(0.66;1.22)	0.83(0.63;1.10)
Physical Pain	1.12(0.95;1.28)	0.89(0.63;1.25)	1.00(0.91;1.10)	1.14(0.93;1.39)	1.00(0.84 ;1.18)	1.29(0.89 ;1.87)
Psychological Discomfort	1.02(0.87;1.18)	0.68(0.49;0.93)*	0.89(0.79;1.00)	0.86(0.71;1.05)	1.02(0.86;1.21)	0.83(0.69;1.00)
Physical Disability	1.56(1.11;2.19)*	1.54(0.93;2.53)	1.06(0.83;1.36)	1.04(0.76 ;1.41)	0.07(0.47;1.06)	0.89(0.50 ;1.60)
Psychological Disability	1.01(0.79;1.30)	0.78(0.53;1.14)	0.78(0.65;0.93)	0.76(0.59;0.98)*	1.26(1.01;1.59)*	1.03(0.69;1.54)
Social disability	1.26(0.93;1.72)	0.89(0.56;1.40)	0.75(0.60;0.95)*	0.78(0.57;1.06)	0.79(0.56;1.13)	0.99(0.57 ;1.70)
Handicap	1.08(0.82;1.41)	0.68(0.44;1.03)	0.89(0.72;1.09)	0.79(0.60:1.04)	0.89(0.56;1.11)	0.66(0.50;0.88)*

All models were adjusted for sex, age, marital status, education level, income, employment status, caries level, periodontal pocket ≥6mm, denture status, had orthodontic treatment, number of contacting pair of teeth and self-reported general health.

5.3 Malocclusion and OHRQoL model

The Malaysian dataset of 323 patients was used to test and modify the conceptual model for oral health related quality of life of malocclusion patients. Three different models were developed and tested for the best pathways in the Locker's conceptual model for malocclusion patients; Basic Model, Modified Model and Final Model.

In the basic model only the pathways hypothesized by Locker in his conceptual model (Figure 6) were considered and analysed. The constructed hypothesized model did not fit well for malocclusion patients and performed poor for all fit indices. The basic model was modified in the light of the modification index and theoretical considerations (Figure 7). Three additional direct paths were suggested by the modification index: functional limitation → pain, functional limitation → discomfort and pain → discomfort. The modified model fitted the data well compared to basic model. Modified model accounted for 18% of the variance in functional limitation, the variance accounted for in the pain variable in this model was 76%, 71% for discomfort, 71% for disability and 82% for handicap.

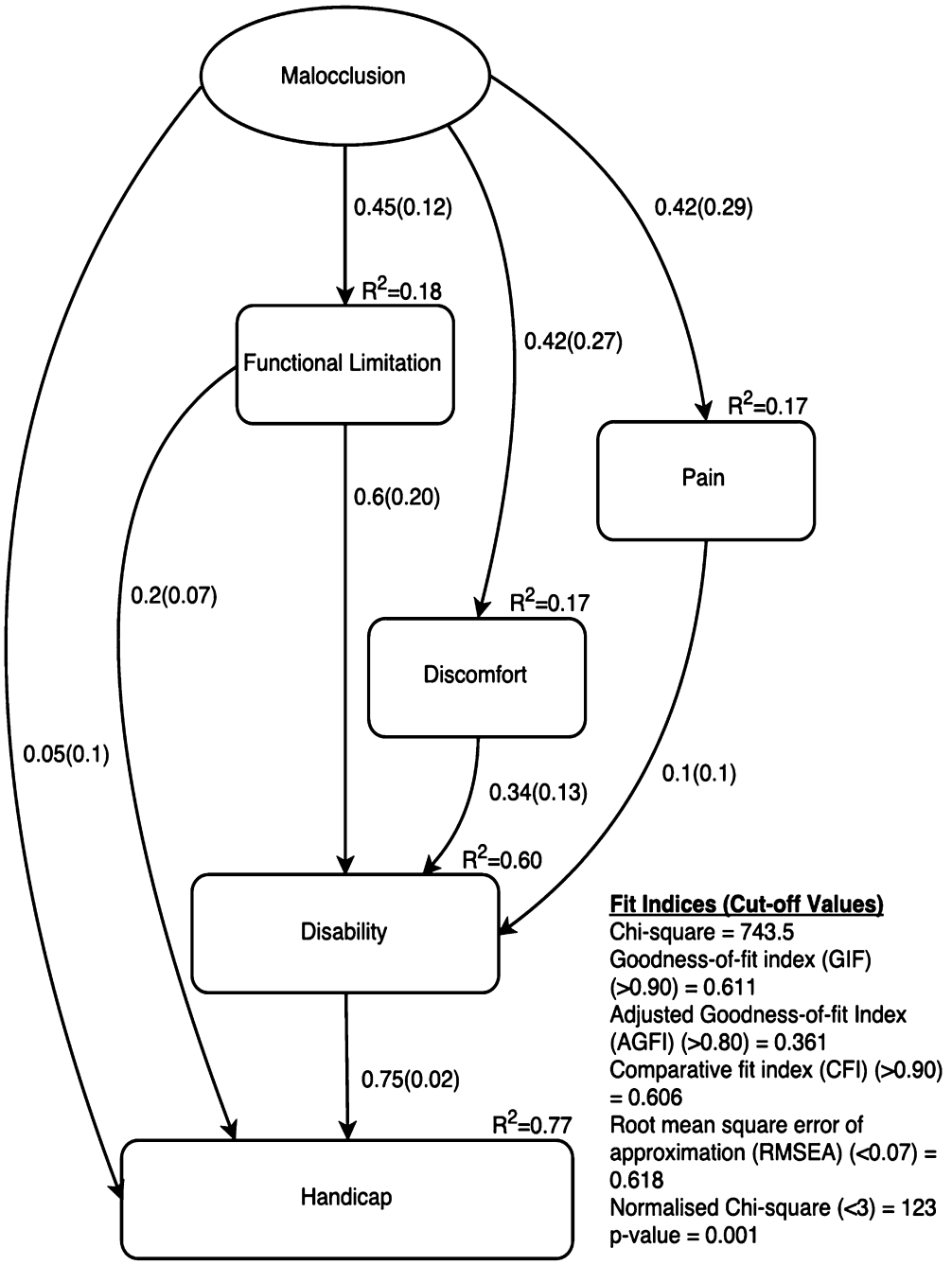

Figure 6: Locker's conceptual model of oral health showing the Pathways hypothesised by Locker and analysed in the basic model. Model showing the relationship of different domains with regression coefficients (standard Error), R^2 and fit indices

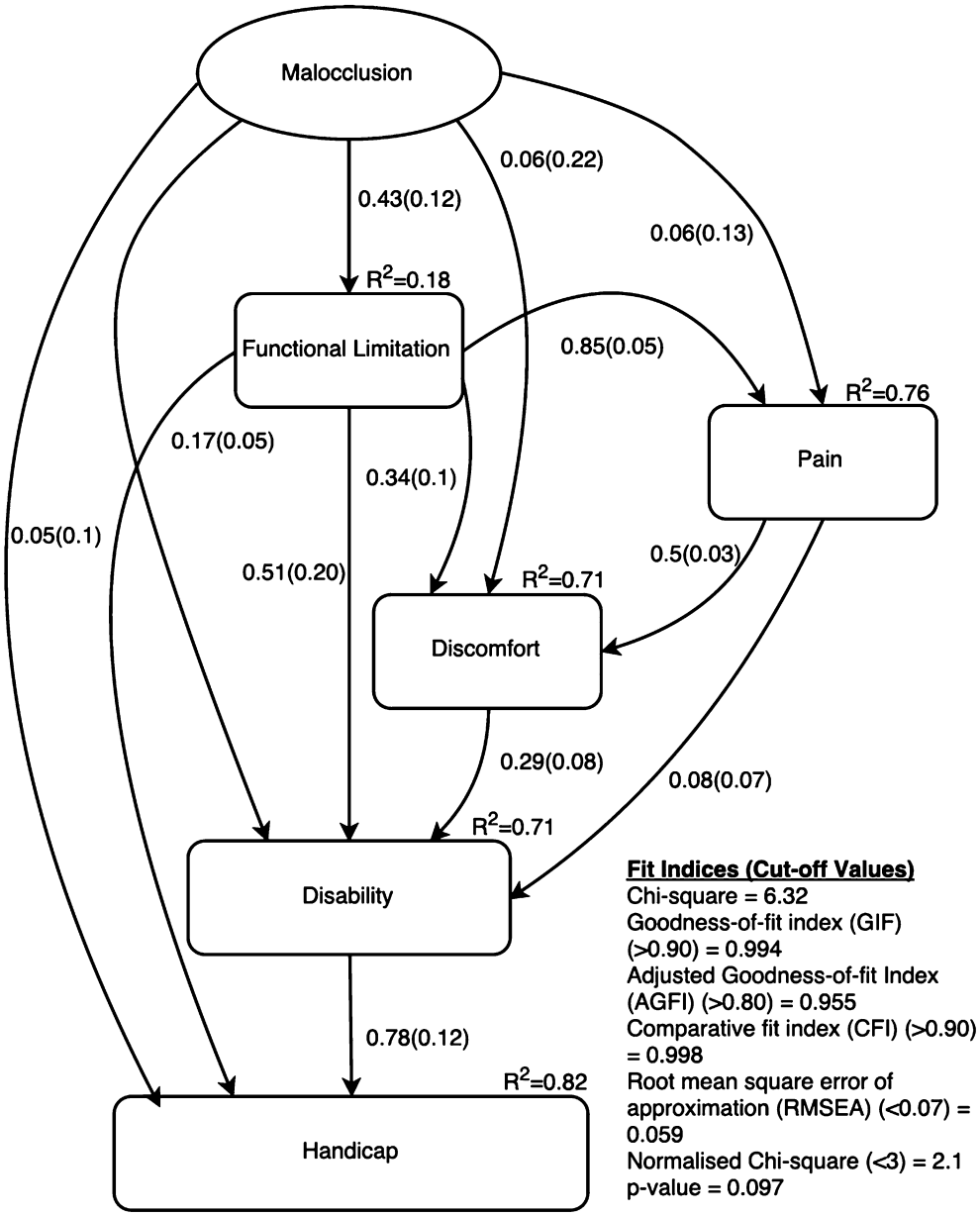

Figure 7: Modified model showing the relationship of different domains (basic model and relationships suggested by modification index) with regression coefficients (standard Error), R^2 and fit indices

Table 14 shows the estimates for the total indirect effects, with bootstrapped SE and bias-corrected 95%CI. As shown, all the indirect pathways were significant; showing that all paths either have full or partial mediation. Full or partial mediation was checked. Full mediation was defined as occurring when a non-adjacent path had a non-significant direct effect and a significant indirect effect. If a path had both a significant direct effect and a significant indirect effect, this was categorized as partial mediation.

Table 14: Total indirect effects between non-adjacent levels for the full structural equation model (Model 2) in Malocclusion patients.

	β	Bootstrap CI	Full or partial mediation	% of total effect
Malocclusion → Pain	0.57	0.429,0.701*	Full	87
Malocclusion → Discomfort	0.62	0.479,0.778*	Full	85
Malocclusion → Disability	1.9	1.46,2.38*	Full	100
Malocclusion → Handicap	0.67	0.511,0.847*	Full	a
Functional Limitation → Discomfort	0.38	0.254,0.507*	Partial	66
Functional Limitation → Disability	0.77	0.521,1.07*	Partial	37
Functional Limitation → Handicap	0.59	0.496,0.673*	Partial	79
Pain → Disability	0.48	0.248,0.721*	Full	64
Pain → Handicap	0.21	0.089,0.327*	Full	100
Discomfort → Handicap	0.24	0.116,0.35*	Full	100

Note: a % could not be calculated due to suppression effect.
*p ≤ .05; β= Regression coefficient; CI = Confidence Interval.

In order to create a more parsimonious model, all non-significant direct paths were removed from the modified model. This final model was then compared to the modified model. There was no difference in the model fit indices, suggesting that the dropped pathways were not important to the final model, and that final model had good fit (Figure 8).

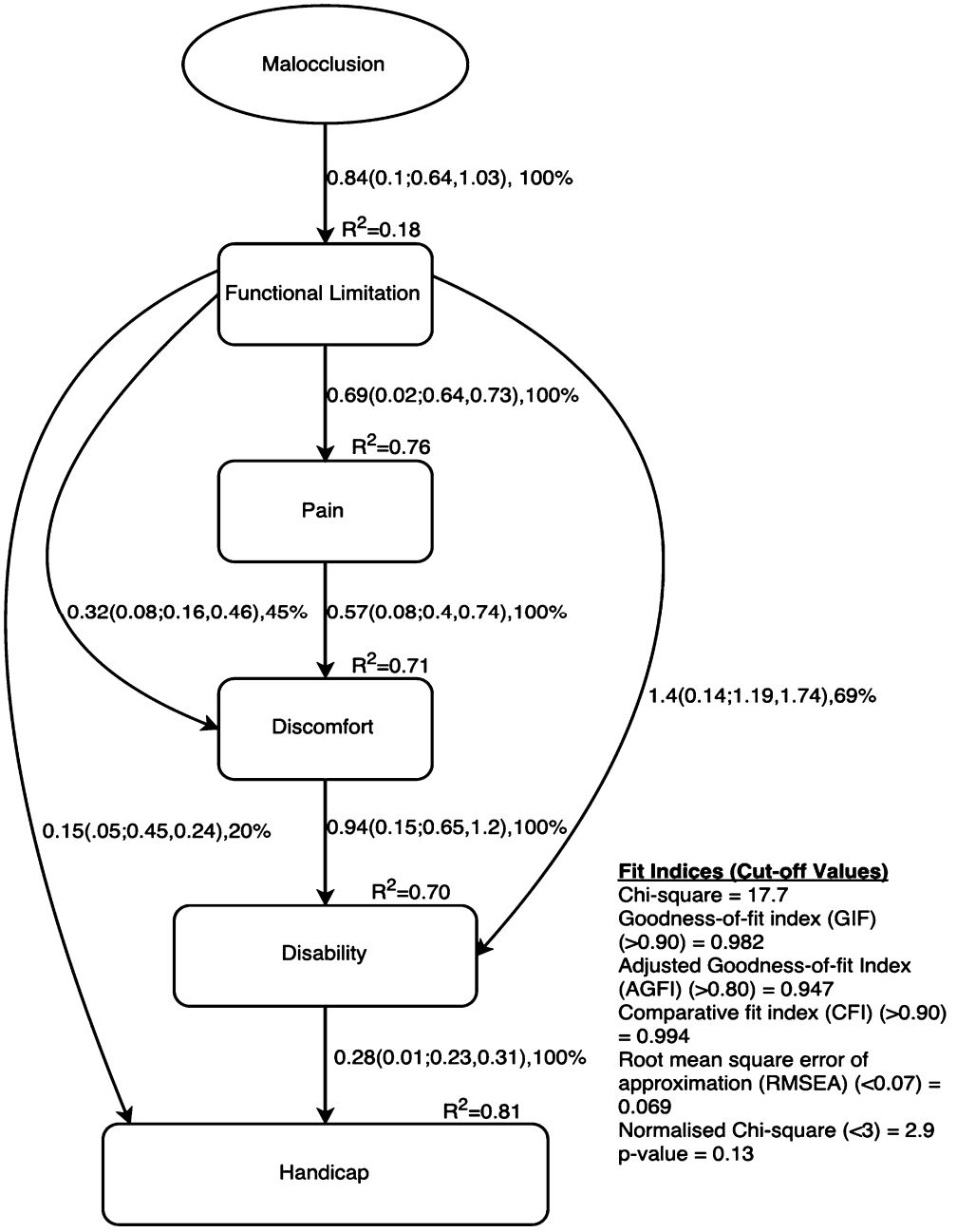

Figure 8: Final model showing the relationship of different domains after dropping all the insignificant paths with regression coefficients (standard Error), R^2 and fit indices.

6 DISCUSSION

6.1 Malocclusion and OHRQoL (I)

This study evaluated the impact of malocclusion on overall OHRQoL and its various domains in 15-25 year olds seeking orthodontic treatment at UiTM Dental clinics. Severity of malocclusion had a gradient effect on patient's OHRQoL, participants with more severe malocclusions reported a greater impact on quality of life. Patients with little treatment need had 5 points higher OHIP-14 score when compared to the participants who do not have any orthodontic treatment need ("no treatment need" group). The participants in this study were patients seeking treatment. They are, therefore, likely to report negative impacts related to their malocclusion. Those patients with a "limited" orthodontic need according to IOTN had OHIP-14 scores which were on average 5 points higher than controls. This is a difference likely to be regarded as important and clinically relevant by patients, the so called "minimally important difference" (Jaeschke et al. 1989). Locker and co-workers have shown that a difference of 5 points on the OHIP-14 additive summary score is likely to be meaningful to patients. It illustrates the limitations of reliance on objective measures such as IOTN for decision making. They are more useful to policymakers as a means of limiting obligation for resource prioritization to those patients with higher levels of severity of malocclusion. Similarly, patients with borderline or high orthodontic treatment need had 9 points or 15 points higher score on OHIP-14 scale, respectively when compared to the participants with "no treatment need". Several previous studies found similar significant relationship between malocclusions and OHRQoL e.g. Heravi et.al., Bernabe et. al. and Foster-Page et. al. (Bernabe et al. 2008b; Foster Page et al. 2005; Heravi et al. 2011). However, some studies did not find any significant relationship between malocclusion and OHRQoL e.g. Taylor et al or Oliveria et al (2008) (de Oliveira et al. 2008; Tonelli et al. 2012). There are several possible reasons for such differences. First, the use of different measures to measure the quality of life. Secondly these studies were carried out with different age groups and it is possible that different age groups have a different perception towards aesthetics and the quality of life. In addition, these studies were carried out in different countries where the cultures, traditions, and social norms make the perception of aesthetics different in each society. Finally, a high frequency or severity of malocclusions in some races and ethnic groups can make malocclusion perceived as normal for the given group and vice versa (Heravi et al. 2011).

This study also examined the relationship of gender, age and education level with OHRQoL. Some studies reported that when compared to males, the female adolescents had higher

dissatisfaction with dental appearance (Peres et al. 2008), since boys are less self-conscious about their appearance (Heravi et al. 2011). In this study, there was no significant difference in the impact of malocclusion on quality of life between males and females. These results were in agreement as reported by Oliveira and Sheiham in adolescents (de Oliveira and Sheiham 2004) and other age groups by Birkeland et al, Hunt et al, 57 and Bernabe´ et al. (Bernabe et al. 2008b; Birkeland et al. 1997; Hunt et al. 2002). A negative association was observed between age and the impact on quality of life due to malocclusion; the impact of malocclusion decreases as age increases. This indicates that the people get adapted with their malocclusion as age increases. Education level had a positive association in the multivariable regression analysis, which may be due to increased self-awareness and self-esteem with increasing education and more interaction with the peers. However, these results should be interpreted with the consideration of small sample size of the study.

Assessing each OHIP-14 domain, malocclusion was highly positively associated with impact on the psychological discomfort and functional limitation domains of OHRQoL. Similar results have been reported in children aged 11-14 years (Foster Page et al. 2005; O'Brien et al. 2007b) and in young adults (de Oliveira and Sheiham 2004; Feu et al. 2010b). This supports the findings of others studies that the most common reason for seeking orthodontic treatment is to correct dental aesthetics and improve self-esteem (Feu et al. 2010b). In this study, significant impact in the handicap domain was present only when patients had high treatment need. Some authors have suggested that malocclusion might become enormously handicapping not because of the functional disability, but because it can adversely affect social relationships and self-perceptions (Prahl-Andersen 1978).

6.2 Malocclusion traits and OHRQoL (II and III)

Impact of the malocclusion traits on OHRQoL was studied in paper II and III using different datasets from Malaysia and Finland. Paper II evaluated the impact of cross-bite on overall OHRQoL and its various domains in 15-25 year olds seeking orthodontic treatment in Malaysian orthodontic patients. This study also evaluated the impact of lower domains of OHIP-14 on higher domains.

Assessing total OHIP-14 and its domain, cross-bite impacts significantly on total OHIP-14 and all its domains. The highest impact was seen on the psychological discomfort and functional limitation domains. These results were similar to the results for all malocclusion patients in paper I and other studies such as in children aged 11-14 years (de Oliveira and Sheiham 2004; Feu et al. 2010b; Foster Page et al. 2005; O'Brien et al. 2007b).

The association of age, gender and education level with OHRQoL in cross-bite patients was similar to that found overall in malocclusion patients. Participants with cross-bite reported a greater impact on quality of life after controlling for the effects of covariates (sex, age, and education level). A negative association was observed between age and impact on quality of life and positive association with education level.

Interesting findings of this study are the impact of lower domain on higher domain. Most of these relationships agree with Locker conceptual model of health and the modified model in paper IV. Functional limitation positively impacts disability and handicap but pain and discomfort don't have a direct impact on handicap; however, they have a direct impact on disability. In this study, impairment (cross-bite) and functional limitation were found to have an impact on handicapness and in modified model it was identified that impairment has an indirect impact on handicapness and functional limitations have direct impact on handicapness. Although some authors have suggested that malocclusion might become enormously handicapping not because of the functional disability, but because it can adversely affect social relationships and self-perceptions (Prahl-Andersen 1978) but this study suggested that the handicap is a function of impairment (cross-bite) and functional limitation and not a function of psychological discomfort. Additionally, the modified model suggested that the psychological discomfort does not have any direct effect on handicapness but it affects indirectly through disability.

Malaysian dataset included the patients from dental clinics who have a perceived need for malocclusion treatment. Therefore, a study with nationally representative sample from Finland was used to see the effect of malocclusion traits on OHRQoL. This study evaluated the impact of three malocclusion traits (Overjet, cross-bite and over-bite) on OHRQoL severity and its domains in a nationally representative sample of Finnish adults > 30 year olds. Our findings demonstrated minor impact of overjet and no impact of cross-bite and over-bite on overall OHRQoL. Previous studies found significant association between malocclusion and OHRQoL in adults (Javed and Bernabe 2015; Johal et al. 2015; Rusanen et al. 2012; Silvola et al. 2012). Most of these studies were done in a clinical setting with patient samples where people with severe malocclusion or existing perceived need were included (Javed and Bernabe 2015; Johal et al. 2015; Rusanen et al. 2012; Silvola et al. 2012). However, this study assessed the relationship between OHRQoL and malocclusion using a population sample in adult population and taking into account potential confounding variables within a representative sample (Scapini et al. 2013). The other reason for minor or low association of malocclusion and OHRQoL is that the people with poorer OHRQoL due to malocclusions have already undergone the orthodontic treatment to correct the malocclusion. However, the sample

included in this study had people with malocclusion with or without previous orthodontic treatment.

Population based studies on children and adolescents found an association between malocclusion and OHRQoL (Sardenberg et al. 2013). Minor or no effect of malocclusion traits on OHRQoL in adults in this study supports the view that the OHRQoL is a 'dynamic' construct similar to the quality of life (Allison et al. 1997). This indicates that the impact of malocclusion reduces with age even without any treatment to correct the malocclusion. It is presumed that increase in the age leads to changes in peoples' internal standards, values, and/or concepts of OHRQoL that consequently changes the cognitive processes in judging their OHRQoL (Reissmann et al. 2012). This is an important future research question to be addressed using a longitudinal study design.

A systematic review found a high level of evidence that malocclusions in the aesthetic zone (anterior crowding, diastema mediale, increased overjet), have negative effects on OHRQoL in children and adolescents (Dimberg et al. 2015). Similarly, in this study only overjet as the only malocclusion trait was significantly associated with the overall OHRQoL. Regarding OHRQoL domains, there is evidence that malocclusion can affect functional limitation by reducing chewing and speech capability (Scapini et al. 2013). In this study, we didn't find any effect of malocclusion on functional limitation, pain and psychological discomfort domains. In the present study, the association between having overjet was significant for the physical disability domains. Questions in this domain address peoples' unsatisfactory diet and interrupted meals because of problem with teeth or mouth. Some studies found the primary impact of malocclusion on OHRQoL in the domains of emotional and social wellbeing, which comprise issues related to aesthetic components and self-esteem (de Paula Junior et al. 2009; Hadzipasic-Nazdrajic 2012; Scapini et al. 2013). In this study, we found association only between over-bite and psychological disability. Theoretical explanations of the link are based on the effect of these conditions on the dissatisfaction with self-image as well as on its impact on people's daily performance (Peres et al. 2008). Studies have reported social impact of malocclusion in children, but we did not find social impact of malocclusion in adults. In children and adolescents, the main reason for the effect on the social domain is due to the teasing by -peers but this teasing goes down with age (Scapini et al. 2013). Taken together, these findings suggest that the impact of malocclusion on OHRQoL is a result of physical and psychosocial features, rather than functional or social problems.

6.3 OHRQoL model for Malocclusion patients (IV)

Locker's conceptual model reflects the concept of oral health that impact moves from a biological basis (impairment) through an impact on the internal individual (functional limitation, pain and discomfort) to aspects impacting the social dimension (disability and handicap) of the individual (Locker and Allen 2007). This model has been empirically tested and modified for various impairments e.g. for edentulous patients, patients with xerostomia (Baker 2007; Baker et al. 2007; Baker et al. 2008; Nuttall et al. 2006). The findings from this study suggest that the final version of the conceptual model of oral health modified in this study is a better representation of the oral health of patients with malocclusion. In Locker's original model, malocclusion predicts functional limitation, functional limitation predicts disability and handicap, discomfort predicts disability and disability predicts handicap; these paths were retained in our final model. However, the most notable three additional paths not included in the base model were, first, functional limitation directly predicts pain; second, functional limitation also predicts discomfort and third, pain directly predicts discomfort. However, these new paths suggested in the modified model mirror what one might a priori hypothesize. For example, it is quite plausible that limited functionality due to malocclusion can cause pain or discomfort. Some studies suggested a new path from pain directly leading to handicap. We didn't find this path with a significant direct effect; this path appears more relevant for acute oral conditions such as trigeminal neuralgia. This extreme consequence is rare in malocclusion patients, and only likely to be reported by a very small number of people in a large population. It is important to recognize that the presence of malocclusion directly predicts only functional limitation; there is no direct path of impact of malocclusion on pain, discomfort, disability and handicap. This would support a view that pain, discomfort, disability and handicap in malocclusion patients ultimately derive from the experience of functional limitation of impact. Therefore, for malocclusion patients the effect of malocclusion on all the domains passes through the functional limitation domain. Functional limitation was also associated directly with pain and discomfort; these pathways were both direct and indirect. Furthermore, as it is based on patient's responses, it may be more useful as a model for examining responses obtained in dental clinical setting rather than as a population setting. Some of the removal and addition of paths from Locker's model are similar to the suggestions made by Nuttal et. al in a population based study (Nuttall et al. 2006). For example, removal of the path "from impairment to handicap" and addition of path "from pain to discomfort".

The complex relationship between malocclusion and domains of OHRQoL has a number of important implications. First, modelling indirect and mediated effects can help explain why relationships between malocclusion and disability and handicap found in previous research

are often weak. Here, functional limitation was a key mediator in the malocclusion to disability or handicap pathway. As indicated in this thesis, this path was fully mediated through functional limitation. Secondly, the findings re-emphasise the importance of assessing a patient's perceived functional limitations alongside the traditional clinical variables, both in research and clinical practice (Baker et al. 2007; Masood et al. 2013). The data suggests that a full understanding of the impact of malocclusion cannot be captured by clinical assessment alone; it should be complemented with the assessment of functional limitation. Such data confirms that malocclusion can influence an individual's wider well-being by directly impacting on everyday physical functioning, and indirectly impacting psychological and social functioning (Baker et al. 2007).

6.4 Strengths

Strength of the Malaysian dataset was the large sample size with proper measurement of the malocclusion using IOTN. The strengths of Finnish dataset were the large nationally representative sample and high participation rates in each part of the survey (e.g. in the home interview, in the questionnaires and in the clinical examination). In addition, as a result of the sampling scheme, the results can thus be generalized for the adult Finnish population >30 year of age.

6.5 Limitations

The findings of this study must be tempered by a consideration of its limitations. First, the participants from Malaysian dataset were from a narrow range of 15-25 year-old orthodontic patients seeking orthodontic treatment with a perceived need at a university clinic in a large urban city of Malaysia. These participants entered in the clinics with perceived need for orthodontic treatment. Therefore, they may have exaggerated the impact in order to increase their chances to get treatment for their malocclusion. Generalizability of the results of this study is also a limitation., Results from this study cannot be extrapolated to the entire youth population with varying levels of malocclusion and orthodontic treatment needs who might have different impacts of malocclusion on their daily activities (Johal et al. 2007). Data from Malaysian studies have assessed the impact of oral conditions on patients' quality of life with convenience samples in dental clinics (Aldrigui et al. 2011; Foster Page et al. 2005; O'Brien et al. 2007b). Therefore, the next study from a nationally representative sample from Finland with and without malocclusion was used.

OHIP-14 and the IOTN were used in Malaysian study. Both instruments are valid and reliable but have some limitations (Feu et al. 2010a). IOTN may be a relatively insensitive instrument to measure minor occlusal traits and irregularities such as midline diastema, spacing of teeth

etc., which mostly affect the patient appearance or the quality of life or about things which a patient is deeply concerned about (Bernabe et al. 2008a; De Baets et al. 2011a). OHIP-14 was developed for adults, but has been successfully applied to adolescents by many authors (Broder et al. 2000; de Oliveira and Sheiham 2004; Feu et al. 2010b; Thomas and Primosch 2002) because adolescents of 12 years of age and above are capable of abstract thinking, reasoning about the timing of past events, and relating them with good or bad experiences (Feu et al. 2010b). Another limitation with OHIP-14 is that it does not elicit the specific cause(s) of the impacts recorded, which can be related to a variety of oral health conditions and not necessarily to the subject's malocclusion. However, the participants from Malaysian study were selected to be free of untreated caries, periodontal disease, malocclusion other than cross-bite and any other oral health problem suggesting the results from OHIP-14 were not confounded with other oral health conditions.

It is also important to recognize the limitations of the study. In the Malaysian dataset, the use of OHIP-14 to measure OHRQoL seems appropriate but appropriateness of OHIP-14 to measure the effect of malocclusion on OHRQoL in a population needs to be explored. A majority of the subjects in population reported no impacts and no effect in overall regression analysis, indicating a large 'floor effect' of impacts measured using OHIP-14 (Slade et al. 2005). In addition, mean severity scores were low in the population, given their potential range from zero to 56. Due to the floor effect, it might be considered that OHIP-14 is not appropriate to measure the effect of malocclusion on OHRQoL in a population (Slade et al. 2005). It indicates the need for a better measure, perhaps a suitable combination of quantitative measure and qualitative measure, giving even more nuanced information on how malocclusions may affect OHRQoL. It has been recognized that the most common reason for seeking orthodontic treatment is to correct dental aesthetics and improve self-esteem (Chen et al. 2014). However, OHIP-14 has only four items (of 14) specific to the assessment of psychological status. It could be inferred that an ideal instrument for orthodontic related quality of life research might need to have more consideration of the psychological aspects as they play important roles in determining how malocclusion affects the quality of life (Chen et al. 2014). While it may be argued that OHIP-14 is not sensitive to minor impacts occurring outside the domains, it is unlikely that these minor impacts would be accorded high priority from a public health perspective (Slade et al. 2005). Malocclusion was not measured in-depth, for example by using IOTN. It was a large national epidemiological health survey and it was difficult to measure each malocclusion trait in more detail.

Both the studies used cross-sectional study design; therefore, causality for the paths in the model cannot be established. A longitudinal study design is required to establish the causality

for the proposed paths in the conceptual model. There are various other models as discussed in the literature review section that conceptualize oral health model. This study used Locker's model as the basic model (OHIP-14 is based on this model as well). It is possible that while the proposed model is a good fit to the data, the alternative models would improve the fit. To confirm the findings of this study, the relative fit of the proposed model against other models e.g. Wilson and Cleary, should be explored in future studies (Sousa and Kwok 2006). The empirically modified model from this study should be considered as one that describes the underlying linkages between the dimensions covered by the OHIP-14 measure when applied to malocclusion patients rather than as a more general conceptual model of oral health. Future work in this area can be starts from a different position to this study. For example, qualitative studies could be undertaken to determine what domain are important to patients with malocclusion. This information could then be used to determine the content of quantitative measures which can be used as an alternative to OHIP-14 for malocclusion patients.

6.6 Implications

Paper I showed that the psychological discomfort domain was the highest impacted domain of OHRQoL in malocclusion patients. Orthodontists should be aware that young patients expect orthodontic treatment to provide not only improved oral functioning and health but enhancement of aesthetics, self-esteem and social life (Tung and Kiyak 1998). Fulfilment of these expectation might be one of the important determinants of the success of malocclusion treatment and when these expectations are not met, this may lead to dissatisfaction with the treatment outcome. The use of the OHRQoL measure as part of the diagnostic procedure in the clinics before starting treatment to find out the impact on psychological and other domain is important, and can provide information on priorities for treatment in order to maximize the patient satisfaction (Agou et al. 2011; Feu et al. 2010b; Johal et al. 2007).

Results of the analysis of the population data from national Health 2000 Survey indicate that the malocclusion is not a major problem in adults at the public health level, and the resources can be allocated to the other major dental public health problems such as dental caries and periodontal disease. In terms of public health, perceived need, often indicated as one of the most accurate predictors of use of dental services (Lahti et al. 2008). Therefore, in adults the low utilization of the services can be expected except for the overjet trait.

7 CONCLUSION

Malocclusion has a negative impact on oral health related quality of life and its domains; this is highest for the psychological discomfort domain among Malaysian young adults for orthodontic treatment. People with overjet had a significantly poorer OHRQoL than people without overjet in a nationally representative population of 30 year olds from Finland. Other malocclusion traits such as cross-bite/scissor-bite and overbite/open bite were not associated with OHRQoL. All these malocclusion traits were associated with disability domains of OHRQoL; overjet was associated with physical disability, cross-bite/scissor-bite was associated with social disability and overbite/open bite was associated with psychological disability. The pathways identified in Locker's (1988) conceptual model of oral health may not be appropriate for describing the relationships between OHRQoL constructs in individuals with malocclusion. Therefore, an alternative model is proposed as part of this study.

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