CHAPTER ONE

INTRODUCTION

Health is a basic human right and oral health is a significant component of general health. Although impaired dental health or poor aesthetics as found in malocclusion is mostly not life threatening, it is an important public health problem. The reasons for the importance are high prevalence, public demand and the impact on individual's and society's anxiety. Due to these reasons, malocclusion becomes worthy of attention. For public health purposes the assessment of occlusion has two main objectives. The first is to screen the population for individual treatment need and priority. The second is to obtain information for the planning of resources and facilities for orthodontic treatment.

Variability in occlusal development and prevalence of malocclusion in different populations had been reported in many studies (Hill, 1992; Tschill et al., 1997; Thilander et al., 2001; Ciuffolo et al., 2005; Abu Alhaija et al., 2005a; Gábris et al., 2006; Lux et al., 2009; Borzabadi-Farahani et al., 2009). The prevalence of malocclusion had been reported to vary from 11% to 93%. These significant variations were not easy to explain and might depend on differences for specific ethnic groups, wide ranges of sample size, subjects' age and differences in registration methods when assessing malocclusion (Thilander et al., 2001).

It is recognised that in planning treatment for occlusal traits and different types of malocclusions, relevant epidemiological data on malocclusion is needed to develop and estimates total need for treatment. In addition, epidemiological information obtained is also needed to develop some form of policy on treatment priority for those needing orthodontic treatment. It is also useful to determine appropriate manpower needed to provide for such treatment (Foster and Menezes, 1976). This is especially true if the government makes provision to provide orthodontic treatment for the public.

It is recognised that information on occlusal traits and orthodontic treatment need priority in developed countries such as the United States, United Kingdom or Norway were obtained between the 1980s and 1990s (Cons et al., 1986; Brook and Shaw, 1989; Espeland et al., 1992). Later publications focused more on the determination of treatment outcomes (Daniels and Richmond, 2000). This shift in interest was related in part to the quality assurance issues in treatment of malocclusion subsequent to the availability of information on malocclusion. On the contrary, developing countries such as Yemen have no baseline data on malocclusion and treatment priority.

Dental occlusion assessment is important as it relates to function and aesthetics. There are several methods that had been used to describe and classify occlusion qualitatively and quantitatively (Tang and Wei, 1993; Hassan and Rahimah, 2007). Qualitative methods describe only the existence or absence of malocclusion. One such example is Angle Classification. Despite the shortcomings of Angle Classification however, it has been widely used as a qualitative epidemiological tool for malocclusion evaluation for decades (Onyeaso, 2004). Quantitative methods on the other hand used clear cut-off points to categorise malocclusion. Many quantitative indices that were developed to study and measure malocclusion had provided useful information on treatment needs but did not give accurate information regarding prevalence of specific malocclusion. For example, due to the hierarchy of the Index of Orthodontic Treatment Need (IOTN), a severe displacement was not scored in cases with tooth impactions. Likewise partially erupted teeth and crossbite was not scored in cases with increased overjet. It is also recognised that there is no evidence of any one measurement method to be the most accurate in measuring prevalence of malocclusion and treatment need. To gain more accurate information with regards to prevalence of malocclusion and treatment need, more than one method need to be used.

Therefore, to obtain relevant epidemiological data on malocclusion, the Fédération Dentaire Internationale (FDI) (Baume et al., 1973) and modified version approved recording of occlusal traits by World Health Organisation (WHO) (Bezroukov et al., 1979) were used to prevent conflicting data related to malocclusions. However, the Index of Orthodontic Treatment Need (IOTN) developed by Brook and Shaw (1989) and modified by Richmond et al. (1995) has been used widely in the literature to estimate real treatment needs for orthodontic patients of different ethnic backgrounds.

Yemen is a developing country in the southwest corner of the Arabian Peninsula. It has a population of 20 million people, life expectancy of 62.9 years, fertility rate of 6.2, inhabitants per physician of 3734 and a ratio of 1:1549 people per hospital bed. Given the many health care problems, malocclusion and orthodontic needs have not been regarded as important. Unfortunately equal lack of attention was also given to caries and periodontal problems, two of the most common dental diseases. However, as Yemen progresses in development, the exposure through mass media also increased the number of patients demanding for orthodontic treatment especially among the younger generation. There is also limited number of orthodontists and orthodontic services available. Given the above, there is a need for Yemen to have basic information on dental care needs, prevalence of malocclusion and orthodontic treatment needs of the population, all of which are not available to date.

The present study is the first national epidemiological study in Yemen. Findings from this study can be valuable for many Yemeni government agencies, especially the Ministry of Health and Ministry of Higher Education. The experience gained by the investigator can help the Yemen government in conducting more epidemiological studies in future especially for more basic dental diseases. In so doing the Ministry of Health will then have a proper database of the dental health status of the Yemeni

population. Information gathered in this study will also pave the way for the Ministry of Health to plan for adequate provision of oral health care including malocclusion treatment for the Yemeni population, especially for the young. In addition, information obtained will also help to provide estimates of manpower needs for orthodontic treatment in the country.

Most important, it is hoped that findings from this study will generate a better understanding of the orthodontic problems in Yemen, thus encouraging those concerned with achieving better health care for the population to debate and discuss these findings. Taking these findings into consideration may improve decision making regarding future delivery of dental services for orthodontic care in the country.

CHAPTER TWO

REVIEW OF THE LITERATURE

2.1 Country Background

2.1.1 Country Profile

The Republic of Yemen is a developing country situated in the extreme south-western corner of Asia, particularly, in the southern half of the Arabian Peninsula. The capital city of the Republic of Yemen is Sana'a. In relation to the borders of Yemen, we can say that it is mediated between two seas; Arab sea and the Gulf of Aden on the south and the Red sea on the west, while on the north and the east, it is bordered by Saudi Arabia and the Sultanate of Oman respectively.

However, in addition to the capital secretariat, the Republic of Yemen is divided into twenty governorates. Yemen is a Muslim country and Arabic is the first and official language of all its population. Geographically, Yemen has diverse states and climate as it is surrounded with the Red sea and the Arab sea from two zones, in addition to its desert climate in the east zone and plateaus and mountains in the north and middle zones.

In Yemen, spring (March - April) and summer (July - August) are considered raining seasons, with spring having highest rainfall. The temperature in the eastern and southern plains can reach as high as 42ºC and as low as 25ºC. As one moves towards higher elevations, temperature decreases gradually to reach 20ºC minimum and 33ºC maximum. In winter, the temperature on the highlands can reach 0ºC. On the other hand, humidity is very high i.e. more than 80%, on the coastal plains. Inland, particularly in the desert areas, it can reach a minimum of 15% (National Information Centre of Yemen, 2002).

2.1.2 Background History

Yemen is considered one of the oldest civilisation centres in the world between the 9th century BC and the 6th century AD, when it was part of several Arab kingdoms such as the Sabaean, Awsania, Minaean, Qatabanian and Hadhramawtian.

In modern times, due to its strategic location, the seaport of Aden was occupied by the British in 1839 and before the opening of the Suez Canal within a short period they were able to enlarge their hegemony into the huge territories of southern Yemen. In 1872, for the second time, the Ottoman Turks came back to Yemen and controlled the northern areas. The Turks entered into competition with the British, and for the first time both parties agreed to divide Yemen into two separate parts, viz. south and north. Later, in the First World War in 1918, the Turks were defeated. As a result they withdrew from Yemen and thus began the era of the Zaidite imams.

However, during the Zaidite imamic rule, the northern part of Yemen entered an extreme seclusion stage, which only ended on 26th of September 1962. From that date, a new era began in the north part of Yemen with the establishment of the Yemen Arab Republic (YAR). Thereafter, on 14th of October 1963 a revolution was waged in south part of Yemen which lasted with the last British garrison evacuated on the 30th of November 1967; hence, the People's Democratic Republic of Yemen (PDRY) in the southern part was established. The division borders of The Ottoman British for the two parts of Yemen however, remained until the unification between the North (YAR) and the South (PDRY) on the 22nd of May 1990 was proclaimed and in turn a new state named the Republic of Yemen began (Salaam, 2000).

2.1.3 Population

Yemen has one of the world's highest birth rates and also a relatively 'young' population. According to the last housing and establishment census in Yemen (2004) the population is 19,721, 643. The population is growing at a rate of 3% per annum, with a population male to female ratio of 1:1 (51% males, 49% females). The average life expectancy is 62.9 years with 50% of the population being in the 0-14 years age groups. The composition of the other two age groups of the Yemen population (15-64) and (65 +) years old are 46.2% and 3.5%, respectively (Central Statistical Organisation Report, 2004).

2.1.4 Geographical Outlook

Yemen is characterised by its unique geographical diversity and is divided into five major geographic regions:

- The Coastal plain region extends sporadically along the coasts of Yemen, where the mountains and hills cut through to reach directly to the sea in more than one place.

- The Mountain region stretches along the farthest borders of Yemen on the north to the farthest point in the south. The average height is 200 metres and peaks to more than 3500 metres. The highest peak is 3666 metres located at Alnabi Shuaib Mountain in the north.

- The Plateau region lies to the middle of the mountain highland and runs parallel to them. It widens towards the Empty Quarter and begins a gradual decline after that. The majority of the surface of this region is formed from rocky desert surface which is cut through by some valleys especially at Hareeb valley.

- The Desert region is sandy and almost devoid of flora except in the areas where rainfalls run through after descending from mountainous areas. The climate here can also be severe with high temperatures and low humidity.

- The Island region comprising many islands spread along the Yemen territorial waters. They have their own peculiar terrain, climate and environment. Most of these islands lie in the Red Sea with the Kamaran Island being the largest inhabited island on the Red Sea. Other islands lie in the Arab Sea. Socotra Island is considered the largest island in the Arab sea (National Information Centre of Yemen, 2002).

2.1.5 Economic Development

The Republic of Yemen has an economic policy based on market systems and improvement of the private sector contributes significantly to the country's economy. To ensure economic stability, the government also encourage foreign investment which will play a leading role in the development process and the achievement of economic growth. The latter is done through a series of improving the overall investment climate (United Nations Development Programme, 2006).

What is most important in addition to what have already been mentioned is that, Yemen has implemented a program of privatisation designed especially to attract more domestic and foreign capital in order to expand the economic activities area. Economically, Yemen is considered one of the promising countries since it has important natural and economic resources, although some of its mineral wealth resources have so far not been exploited, such as in the area of oil and gas. The average growth rate of Yemeni economy per year ranges between 10-18% at recent prices, (Ministry of Finance Report, 2004).

2.1.6 Dental Education and Services in Yemen

The dental services in Yemen are provided by both private offices and government dental clinics. The latter services are provided by the dental schools, five public and one private dental school. The first public dental faculty in Yemen was opened in 1997 at Thamar University. The others are located in Sana'a, Aden, Ibb and Al-Hudaydah, the only private institution is located at Sana'a. No postgraduate training in orthodontic or any other specialisation in dentistry is available.

Government dental services in Yemen for the public are limited to provision of fillings, extractions and minor surgery. Specialised treatments such as orthodontics are only available in dental schools and private clinics. General dental services provided by dental schools for the public are usually at out-of-pocket charge. Patients are charged very minimally for orthodontic and other specialty treatment.

As Yemen develops, the demand for orthodontic treatment has increased, such that in some dental faculties the waiting period is up to three years. There is no prioritisation of treatment and those who are in real need of treatment are being deprived and have to wait along with less needy cases. In current time in Yemen, the patients are considered to need orthodontic treatment when diagnosed in Class II or III according to anterio-posterior occlusal relationship of Angle or Incisors Classifications. Orthodontic treatment is provided by practitioner orthodontists who graduated from the Middle East, Asia and East Europe, all of whom are concentrated in the central governorates where the dental faculties are located (Annual Statistical Health Report, 2008). General dental practitioners who do not have orthodontic qualification also treat orthodontic cases and there is no control or monitoring of the services provided by these general practitioners.

2.2 Dental Occlusion

There are several definitions of dental occlusion. Beyron (1954) described it as the normal relationship of inclined planes of the maxillary and mandibular teeth when the jaws are closed. Houston (1976) defined occlusion as the relationship of the teeth of the maxilla and mandible when there is maximum cuspal occlusion (full interdigitation). The definition of occlusion by Foster (1990) says it is any position in which the upper and lower teeth come together in contact, also known as static position.

The term dental occlusion thus refers not only to contact at an occlusal interface, but also to the growth and development factors of the jaws, masticatory system and teeth. Recent studies of occlusion confirmed that the dental occlusion complex system including teeth, joints and muscles of the head and neck together as one system of functional units. Occlusion also involves an understanding of the neuromuscular systems (Staley, 2001 and Ash and Nelson, 2003).

2.2.1 Ideal Dental Occlusion

The first serious discussion and analyses of occlusion emerged during the 1890s with the emergence of basic information for diagnosing orthodontic cases between orthodontists. More prominent was that brought about by Angle who demonstrated that it is necessary to be familiar with both of the ideal and normal occlusion before diagnosing any case of malocclusion. Houston and Tulley (1986) recommended four concept of ideal occlusion;

1) Ideal inclinations of the teeth should be with maxillary and mandibular jaws.
2) Each mandibular tooth contacts with the corresponding maxillary tooth, except incisors anterior to it.

3) Centric relationship of mandible by condyles positions in the glenoid fossa occurred when the teeth in maximum intercuspation.
4) Ideal function of occlusion is occurred by mandible movement. ‘cuspid of posterior segments and canines guidance governs the lateral movement of the mandible.

Recently, Da Silva (2008) further described the ideal occlusion as an anatomically perfect arrangement of the teeth.

2.2.2 Normal Dental Occlusion

Normal dental occlusion was generally observed in population, Andrews (1972) the father of straight wire appliance gave six keys to describe normal occlusion namely;

1. Molar relationship: the mesiobuccal cusp of the maxillary first molar occludes with the mesial surface of mesiobuccal groove of the mandibular first molar.
2. Crown angulation (tip): it is the crown angulations and not the angulation of the entire tooth. The gingiva of the long axis of each crown is distal to incisal portion varying with each individual tooth.
3. Crown inclination (torque): this refers to labio-lingual or bucco-lingual inclination of the long axis of the crown, not the inclination of the long axis of the entire tooth.
4. Rotation: all teeth are in contact with no rotations.
5. Spaces: all teeth in tight contact points without any spaces.
6. Occlusal plane: varies plane of occlusion from flat to a slight curve of spee.

Houston (1976) defined normal occlusion as the occlusion which satisfied the requirement of function and aesthetics but in which there were minor irregularities of individual teeth. Roth (1981) later added function features to the earlier six keys to normal occlusion, namely bilateral contacts of the teeth in posterior segments should

coincide when in centric occlusion, normal canine position guide lateral movement of mandible and the lower incisor edges provide guidance by passing along the palatal contour of the upper incisors.

In a more recent work, Staley in (2001) defined normal dental occlusion to include variation in teeth positions and relationships that diverged in minor ways from the ideal occlusion.

The above six keys and function features contributed individually and collectively to the total scheme of dental occlusion and is therefore viewed, to date, as being essential to successful orthodontic treatment.

2.2.3 Malocclusion

Malocclusion was defined as considerable deviations from the ideal occlusion that might be considered aesthetically or functionally unsatisfactory (Houston and Tulley, 1986; Ash and Nelson, 2003).

2.2.3.1 Aetiology of Malocclusion

Multiple theories had been suggested to explain the aetiology of malocclusion. The aetiology were divided in two categories; hereditary and environmental (Mossey, 1999; Rani, 2001).

Potter and Nance (1976) reported that the inheritance of tooth size and dental occlusion occurred as a result of multigenic system in which the action of multigens together with environmental factors would present the final results of the dental character. In addition, Houston and Tulley (1986) reported that malocclusion prevalence had increased in modern societies, relating this to environmental factors.

Harris and Johnson (1991) studied the heritability of skeletal and tooth based variables in a longitudinal study at 4, 14 and 20 years. They demonstrated that several craniofacial parameters important in craniofacial growth showed significant heritability. In contrast, occlusal and arch parameters were affected minimally by genetic factors and experienced increasing influence from environmental factors throughout postnatal growth.

In another study, Cassidy and co-workers (1998) studied the genetic influence on dental arch form. They found that arch width, molar and canine relationships showed appreciable genetic influence while tooth rotations and overjet were primarily influenced by environmental factors. A number of primarily environmental causes were also known. These included habits, trauma, caries, periodontal disease, chronic nasal

obstruction with mouth breathing and reduced masticatory stresses resulting from the soft consistency of food in urbanised society.

2.2.3.2 Prevalence of Malocclusion

The prevalence of malocclusion varies widely in different countries and populations of the world. This variation between different ethnic groups has been attributed to the effect of natural selection in breeding versus out-breeding and environmental factors (Sarver et al., 2000).

In more recent years, malocclusion has been reported higher in prevalence and severity. Evensen and Øgrade (2007), who investigated the prevalence and severity of malocclusions in a sample of medieval Norwegians and compared these findings with a recent sample, found a significant increase of malocclusion in the last 400 to 700 years in Norway.

Different studies to assess malocclusion had also been conducted in the Middle East countries. Their findings showed a high prevalence of dental occlusal anomalies. Behbehani et al. (2005) evaluated the prevalence and severity of malocclusion in an adolescent Kuwaiti population. They found that more than 70% of the Kuwaiti sample had moderate to severe malocclusion. Gelgör et al. (2007) in their study on a Turkish sample reported that normal occlusion was only in as little as 10.1% of the sample. Majority of the sample (89.9%) was found to have different types of malocclusion. More studies on the prevalence of malocclusion among different populations in the world are summarised in Table 2.1.

Table 2.1: Summary of studies on prevalence of malocclusion

Authors (year)	Population	Subjects		Registration Method	Malocclusion Prevalence (%)
		N	Age (years)		
Krzypow et al. (1975)	Israeli	538	18-20	Angle Classification	95.9
Lew et al. (1993)	Chinese	1050	12 - 14	Foster and Day (1974)	92.9
Tschill et al. (1997)	French	789	4 - 6	FDI method	57.6
Thilander et al. (2001)	Colombian	1441	13 - 17	Björk et al. 1964	88
Onyeaso (2004)	Nigerian	636	12 - 17	Angle Classification	76
Ciuffolo et al. (2005)	Italian	810	11 - 14	Criteria of National Health and Nutrition US Survey (Brunell et al. 1996)	93
Abu Alhaija et al. (2005a)	Jordanian	1003	13 - 15	Björk et al.1964	92
Gábris et al. (2006)	Hungarian	483	16 - 18	WHO method (1986)	70.4
Jonsson et al. (2007)	Icelandic	829	31 - 44	Björk et al. 1964	54.5
Gelgör et al. (2007)	Turkish	2329	12 - 17	Angle Classification	89.9
Dhar et al. (2007)	Indian	812	11 - 14	WHO method (1999)	38.9
Borzabadi-Farahani et al. (2009)	Iranian	502	11-14	Angle Classification	77.1
Martins and Lima (2009)	Brazilian	264	10 - 12	Angle Classification	74.2
Mtaya et al. (2009)	Tanzanian	1601	12 - 14	Modified Björk method by Al-Emran et al. (1990)	63.8
Jamilian et al. (2010)	Iranian	350	14 - 17	IOTN	83.7
Ekuni et al. (2011)	Japanese	641	18 - 19	IOTN	40.0

2.2.3.3 Psychological Effect of Malocclusion

Psychologically malocclusion has an effect on a person's own sense of well-being and self-esteem. Researches on the psychological effects of dento-facial deformity observed that subjects with malocclusion were unhappy with their appearance and had less self-confidence (McDonald and Ireland, 1998).

Many studies had reported that adolescents who perceived their dental arrangement as irregular tended to neglect oral health and hygiene (Klages et al., 2004; Hassan and Amin, 2010). This tendency might be stronger in individuals who experienced negative social and psychological impacts of their dental appearance. Additionally, several studies found direct effect and positively associated malocclusion with appearance dissatisfaction and interpersonal sensitivity (Marques et al., 2009; Badran, 2010; Ekuni et al., 2011). In contrast young adults with previous exposure to orthodontic treatment indirectly had shown more stable pattern of dental compliance and better oral health (Klages et al., 2007; Agou et al., 2011).

It was interesting to note that attractive persons without malocclusion were regarded as being more popular and perceived as having greater intelligence and also showed more self-esteem than subjects with malocclusion (Jung, 2010).

2.3 Occlusal Traits

Common occlusal traits presented in this chapter are based on the following:

i. Dental discrepancies
ii. Space discrepancies
iii. Occlusal discrepancies in anterio-posterior relationship
iv. Occlusal discrepancies in vertical relationship
v. Occlusal discrepancies in transversal relationship

2.3.1 Dental Discrepancies

Of the many dental discrepancies, missing permanent teeth were the most often recorded (Garner and Butt, 1985; Al-Emran et al., 1990; Abu Alhaija et al., 2005a; Ciger and Akan, 2010). The missing teeth could be impacted, congenitally absent or extracted teeth. Oral examination and interviewing of the subject were the methods to

assess missing teeth (Björk et al., 1964; Baume et al., 1973, and Bezroukov et al., 1979).

Impacted tooth is defined as a tooth that was blocked from eruption by a physical barrier such as another tooth. The major reason for impacted tooth occurrence was the small size of arches (Richards, 2001). A number of studies reported the prevalence rates of impacted teeth to be from 1.8 to 10% of the population (Al-Emran et al., 1990; Abu Alhaija et al., 2005a).

Congenitally absent teeth are genetically associated tooth agenesis. It is commonly associated with other dental discrepancies such as structural anomalies and delayed eruption (Vastardis, 2000). Hypodontia is the general terminology most often used when describing the congenitally absent teeth, or specifically in the case of absence of one to six teeth excluding third molars. Oligodontia is used for the absence of more than six teeth while the term anodontia is an extreme case of total absence of teeth.

A number of studies reported the prevalence rates of congenitally absent teeth to be from 2 to 11% of the population (Hamdan, 2001; Chung et al., 2008). Overall, the most common teeth in the arch reported as congenitally absent were the mandibular second premolar, permanent maxillary lateral incisor and maxillary second premolar (Mattheeuws et al., 2004). The results of some studies on missing permanent teeth are summarised in Table 2.2.

Table 2.2 Summary of studies on prevalence of impacted, congenital and supernumerary teeth

Authors (year)	Population	Subjects		Impacted teeth (%)	Congenital absent teeth (%)	Super-numerary teeth (%)
		N	Age (years)			
Garner and butt (1985)	Kenyan	505	13 - 14		5.7	
	Black Americans	445	13 - 15		5.4	
Al-Emran et al. (1990)	Saudi Arabian	500	14	10.4	4	
Diagne et al. (1993)	Senegalese	1708	11 - 19		7.6	0.4
Hamdan (2001)	Jordanian	320	14 - 17		2	
Thilander et al. (2001)	Colombian	1441	13 - 17	3.1	3.2	1.8
Abu Alhaija et al. (2004)	Jordanian	1002	12 - 14	17		
Fekonja (2005)	Slovenian	212	mean 12.7		11.3 (with radiographs)	
Abu Alhaija et al. (2005a)	Jordanian	1003	13 - 15	1.8	6	
Ezoddini et al. (2007)	Iranian	80	Not specified	8.3 (with radiographs)		3.5
Chung et al. (2008)	Koreans	1622	Not specified		11.2 (with radiographs)	
Ciger and Akan (2010)	Turkish	213	10 - 24	7	6	0.0
Gomes et al. (2010)	Brazilian	1049	10 - 15.7		6.3	
Vahid-Dastjerdi et al. (2011)	Iranian	1751	9 - 27			0.74

Supernumerary teeth are extra teeth in the dental arches and may occur in the primary or permanent dentition. Richards (2001) stated that as a general rule, the cause of an extra tooth is due to migration of the initiating cells from near the neural crest to the site of tooth formation. The majority of supernumerary teeth occur in the maxilla, with the most common location being between maxillary central incisors and the more rare being in the canine region (Davis, 1987).

Supernumerary teeth are classified according to their morphology; they have been described as supplemental, rudimentary, tuberculate, or molariform of these, the supplemental tooth supernumerary that is comparable to the morphology and structure of normal dentition. Another classification is according to their sites, examples are midline and paramolar or distomolar (molar area). The prevalence of supernumerary teeth in the general population has been reported to range from 0 to 3.5% according to the study sample and race (Thilander et al., 2001; Ezoddini et al., 2007; Ciger and Akan, 2010).

2.3.2 Space Discrepancies

2.3.2.1 Crowding and Spacing

Space discrepancy is the difference between the spaces needed in the dental arch and the available space in the dental arch. This discrepancy can be crowding or spacing of the teeth (Nance, 1947). Arch length discrepancy is measured as available arch length minus required arch length, with negative values indicating crowding while positive values indicate spacing.

Foster and Day (1974) reported that excess of available arch space were limited and clinically less prevalent than a lack of arch space. This was confirmed by orthodontic patients and those seeking orthodontic treatment who displayed more crowding than spacing.

Crowding, defined as lack of adequate space for the teeth to be aligned over the dental arch, has been studied by relating the teeth dimensions to arch dimensions (Gilmore and Little, 1984). The investigators found that there was a significant relationship between dental crowding and tooth-size arch-size. Bernabé and Flores-Mir (2006b) noted that tooth size was not the only factor in dental crowding, but that one should also consider

the crown proportion. Poosti and Jalali (2007) stated that malocclusion was the result of either a skeletal or a dental discrepancy, on the other hand crowding was a result of a tooth-size-arch-length discrepancy. According to these authors tooth size appeared to have a greater role in developing dental crowding. Crowding in the permanent dentition was one of the most prevalent occlusal traits reported by many investigators including Behbehani et al. (2005), Gelgör et al. (2007) and Borzabadi-Farahani et al. (2009).

Dental spacing was identified as the amount of space available that exceeds the space needed for the teeth to be aligned over the dental arch. The prevalence of spacing had been found to be higher in the African population than Caucasians (Kerosuo et al., 1991; Mtaya et al., 2009). Spacing was also found more often in the maxilla than mandible, whilst crowding was found to be more common in the mandible (Mugonzibwa et al., 2008). Spacing with one or more interproximal spaces in an otherwise normal dental arch was often viewed as a kind of malocclusion which ought to be treated orthodontically, mainly for aesthetic reasons.

Different criteria were used to assess crowding and spacing. Steigman and Weissberg (1985) registered spacing of 0.2 mm or more, while Behbehani et al. (2005) measured crowding and spacing as more than 0.5 mm. Many authors had recommended crowding and spacing more than or equal 2 mm (Björk et al., 1964; Baume et al., 1973; Bezroukov et al., 1979; Mtaya et al., 2009). Table 2.3 shows studies on crowding and spacing.

Table 2.3: Summary of studies on prevalence of crowding and spacing

Authors (year)	Population	Subjects		Findings (%)		
		N	Age (years)	Crowding		Spacing
Krzypow et al. (1975)	Israeli	538	18 - 20	50.5		20.1
Lavelle (1976)	British	1330	15 - 20	Maxilla	m= 18.8 f= 27	m= 8.2 f= 5
				Mandible	m= 29 f= 32	m= 5 f= 3
Gardiner (1982)	Libyan	479	10 - 12			20.3
Mohlin (1982)	Swedish	272	20 - 45	Maxilla	23	7
				Mandible	42.9	5
Isiekwe (1983)	Nigerian	617	10 - 19	15.1		
Gosney (1986)	British	207	5 - 16	m= 71 f= 69		m= 67 f= 42
Kerosuo et al. (1988)	Tanzanian	642	11 - 18	16		
Al-Emran et al. (1990)	Saudi Arabia	500	14	Maxilla	19.4	17
				Mandible	23.4	8
Salonen et al. (1992)	Swedish	669	≥ 20	m= 14.2 f= 22.6		m= 12.7 f= 7.7
Thilander et al. (2001)	Colombian	1441	13 - 17	mild 41.5, moderate 13, severe 4.2		23
Lauc (2003)	Croatian	224	11 - 18	57%		8
Onyeaso (2004)	Nigerian	636	12 - 17	20.1		
Tausche et al. (2004)	German	1975	6 - 8	Maxilla (mild 19.4, moderate 10.2, severe 1.8)		
				Mandible (mild 32.8, moderate 12.7, severe 1.6)		
Abu Alhaija et al. (2005a)	Jordanian	1003	13 - 15	50.4		26.7
Gábris et al. (2006)	Hungarian	483	16 - 18	14.3		17

Continued Table 2.3

Gelgör et al. (2007)	Turkish	2329	12 - 17	mild 25,moderate 11.3, severe 1.8		
Jonsson et al. (2007)	Icelandic	829	31 - 44	Maxilla	7.1	4.7
				Mandible	13.4	2.2
Mugonzibwa et al. (2008)	Tanzanian	212	ES4	9		23.6
Mtaya et al. (2009)	Tanzanian	1601	12 - 14	14.1		21.9
Martins and Lima (2009)	Brazilian	264	10 - 12	62.5		
Borzabadi-Farahani et al. (2009)	Iranian	502	11 - 14	Maxilla (mild 38, moderate 20.5, severe 16.7)		18.9
				Mandible (mild 41, moderate 21.9, severe 10.8)		20.7
Perillo et al. (2010)	Italian	703	12	45.9		

m = male, f = female, ES4= emergence stage 4 (complete permanent dentition)

2.3.2.2 Maxillary Midline Diastema

Maxillary midline diastema is a space between the maxillary central incisors which may be associated with the presence of a hyperplastic fraenum. A midline diastema during the mixed dentition stage is part of normal dental development (Huang and Creath, 1995). Midline diastema in permanent dentition in Africa, however, is regarded as a mark of natural beauty and not as malocclusion (Onyeaso, 2004). On the contrary, many occlusal studies in the Middle East and Caucasian populations regarded midline diastema as malocclusion (Al-Emran et al., 1990; Martins and Lima, 2009). Maxillary midline diastema in addition to spacing was also reported in malocclusion studies conducted by Behbehani et al. (2005) and Gelgör et al. (2007). Some investigators recorded midline diastema when it was 1 mm and more (Lauc, 2003; Onyeaso, 2004). On the other hand, several studies related to recording of occlusal traits recommended that the registration of diastema at 2 mm and more (Björk et al., 1964; Baume et al.,

1973; Bezroukov et al., 1979). Summary of the studies on maxillary midline diastema is as shown in Table 2.4.

Table 2.4: Summary of studies on prevalence of maxillary diastema

Authors (year)	Population	Subjects		Maxillary Diastema (%)
		N	Age (years)	
Al-Emran et al. (1990)	Saudi Arabian	500	14	3.6
Thilander et al. (2001)	Colombian	1441	13 - 17	3.7
Lauc et al. (2003)	Croatian	224	7 - 14.	12.9
Onyeaso (2004)	Nigerian	636	12 - 17.	36.8
Abu Alhaija et al. (2005a)	Jordanian	1003	13 - 15	6.9
Behbehani et al. (2005)	Kuwaiti	1299	13 - 14	6.9
Gábris et al. (2006)	Hungarian	483	16 - 18	7.6
Gelgör et al. (2007)	Turkish	2329	12 - 17.	7.0
Ajayi (2008)	Nigerian	441	11 - 18	19.5
Martins and Lima (2009)	Brazilian	264	10 - 12.	14.8

2.3.3 Occlusal Discrepancies in Antero-posterior Relationship

2.3.3.1 Overjet

Horizontal overlap (overjet) has been defined as the projection of maxillary incisors beyond their antagonist's mandibular incisors in the horizontal plane when the teeth were in intercuspal position. It was considered as the most important indicator for dental occlusion in the antero-posterior relationship (Houston, 1983). Different criteria for measuring overjet had been used. Crabb and Rock (1986) and Jones (1987) measured overjet as the distance from the right or the left central incisor to labial surface of the matching mandibular incisor. However, other investigators defined overjet as the distance

from the most labial point of the incisor edge of the maxillary incisors to the most labial surface of the corresponding mandibular incisor and parallel to the occlusal plane (Richards, 2001; Borzabadi-Farahani et al., 2009).

Researchers had varied characteristics to define increased overjet, for examples Isiekwe (1983) at greater than 3 mm, Thilander et al. (2001) at more than 4 mm and Haynes (1973) at 5 mm or more. Most studies on the prevalence if malocclusion in various parts of the world however, classified overjet as being increased of it as 6 mm or more (Bezroukov et al., 1979; Mũniz, 1986; Diagne et al., 1993; Jonsson et al., 2007; Borzabadi-Farahani et al., 2009).

A mandibular or reverse overjet value is defined as having all four maxillary incisors lying lingual to the opposing mandibular incisor. This has also been referred to as negative overjet (Bezroukov et al., 1979; Abu Alhaija et al., 2005; Mtaya et al., 2009). Summary of the findings of reported studies is as shown in Table 2.5.

Table 2.5: Summary of studies on prevalence of overjet

Authors (year)	Population	Subjects		Overjet type and measurement		
		N	Age (years)	Increased (%)	Measurement category	Reverse (%)
Mũniz (1986)	Caucasian	1554	12 - 13	14.1	≥ 6 mm	1.2
	Amerindian			5.3		1.8
Al-Emran et al. (1990)	Saudi Arabian	500	14	18.4	> 5 mm	3.2
Diagne et al. (1993)	Senegalese	1708	11 - 19	6.2	≥ 6 mm	1.1
Tang (1994)	Chinese	201	20 mean	14.9		15.4
Thilander et al. (2001)	Colombian	1441	13 - 17	25.8	> 4 mm	6.9
Onyeaso (2004)	Nigerian	636	12 - 17	16	> 3 mm	0
Tausche et al. (2004)	Garman	1975	6 - 8	25.3	> 3.5 - 6 mm	1.4
				6.1	> 6 mm	

Continued Table 2.5

Behbehani et al. (2005)	Kuwaiti	1299	13 - 14	88.2	> 0.5 - 6 mm	4
				7.8	≥ 6.5	
Abu Alhaija et al. (2005)	Jordanian	1003	13 - 15	24.7		1.9
Gelgör et al. (2007)	Turkish	2329	12 - 17	25.1	> 3 mm	10.4
Jonsson et al. (2007)	Icelandic	829	31 - 44	10.6	≥ 6 mm	
Lux et al. (2009)	Garman	494	9	14	> 6 mm	
Mtaya et al. (2009)	Tanzanian	1601	12 - 14	11.1	5 - 8.9 mm	8.4
				0.4	≥ 9 mm	
Borzabadi-Farahani et al. (2009)	Iranian	502	11 - 14	92.2	< 6 mm	4.2
				3.6	≥ 6 mm	

2.3.3.2 Anterior Crossbite

Salzmann (1968) defined anterior crossbite as the situation of lingual position of the maxillary incisors to their opposing mandibular incisors, when both arches are in centric occlusion. In their study, Foster and Day (1974) confined anterior crossbite to the involvement of one or two incisors. Occlusal measurement studies by Baume et al. (1973) and Bezroukov et al. (1979) however, recommended recording anterior crossbite when the inverted maxillary incisors involved one, two or three incisors.

The most common tooth involved with anterior crossbite is the maxillary lateral incisors. This may be due to their developmental position, which might have led to tooth attrition and periodontal pockets as stated by Richards (2001). The prevalence of anterior crossbite in the general population has been reported to be within the range of 1 to 9% and varied greatly according to geographical location and race (Lauc et al., 2003; Abu Alhaija et al., 2005a; Lux et al., 2009). Table 2.6 presents a summary of studies on anterior crossbite.

Table 2.6: Summary of studies on prevalence of anterior crossbite

Authors (year)	Population	Subjects		Anterior crossbite (%)
		N	Age (years)	
Krzypow et al. (1975)	Israeli	538	18 – 20	6.3
Můniz (1986)	Caucasian	1554	12 – 13	4.1
	Amerindian			3.2
Al-Emran et al. (1990)	Saudi Arabian	500	14	3.8
Diagne et al. (1993)	Senegalese	1708	11 – 19	1.6
Thilander et al. (2001)	Colombian	1441	13 – 17	7.3
Lauc et al. (2003)	Croatian	224	7 – 14	0.9
Behbehani et al. (2005)	Kuwaiti	1299	13 – 14	1 incisor 12.1
				2 incisors 7.1
				3 incisors 1.6
Abu Alhaija et al. (2005a)	Jordanian	1003	13 – 15	5.2
Jonsson et al. (2007)	Icelandic	829	31 – 44	1.2
Lux et al. (2009)	Garman	494	9	8.5
Borzabadi-Farahani et al. (2009)	Iranian	502	11 - 14	8.4

2.3.3.3 Bimaxillary protrusion

Bimaxillary protrusion is a condition characterised by protrusive and proclined maxillary and mandibular incisors with an increased procumbency of the lips. It is seen commonly in African (Isiekwe, 1990; Farrow et al., 1993), Asian (Tan, 1996) and Caucasian (Thilander et al., 2001) populations, but it can also be seen in almost every ethnic group. According to Lamberton et al. (1980), aetiology of bimaxillary protrusion is multifactorial and consists of a genetic issue as well as environmental factors, such as mouth breathing, tongue and lip habits, and tongue volume.

Hussein and Abu Mois (2007) used cephalometric radiographs to determine the morphological features of bimaxillary protrusion in a strictly Palestinian population. They reported that bimaxillary protrusion was associated with a greater lower incisor proclination when referred to the A-pogonion line. However, they also showed that Palestinians had an inclination toward more incisor proclination.

There are controversial opinions with respect to the response of soft tissue to retraction of the maxillary and mandibular incisors of bimaxillary protrusion. Finnoy et al. (1987) looked at profile changes during and after orthodontic treatment. Their study showed there was no significant correlation between patients treated with four premolar extractions and profile improvement. Other studies showed that there were definite association between incisors retraction and changes in soft tissue. Lew (1989) studied the profile changes after extraction of four first premolars followed by orthodontic treatment of bimaxillary protrusion among Asian adults. The results showed a significant improvement in maxillary and mandibular incisors protrusion, lip length and protrusion. Similar results were obtained in other studies (Caplan, 1997; Kusnoto and Kusnoto, 2001; Jamilian et al., 2008).

2.3.4 Occlusal Discrepancies in Vertical Relationship

2.3.4.1 Overbite

Overbite is the vertical overlap of the maxillary teeth over the mandibular teeth when the posterior teeth are in contact. To assess overbite epidemiologically, detailed baseline of different measurements of overbite are needed.

Draker (1960) suggested the use of a pencil for making the position of the maxillary incisal edge on the labial surface of the mandibular incisors. The distance was then measured. In 1972, Haynes used a third of the mandibular incisor overlap for overbite

assessment. Other studies used indirect methods for overbite measurement such as on a study model, digital models and radiographs. However these methods were usually restricted to studies of small sample size. Cooke and Chawla (1981) introduced their new method which was based on double silicon squash bite technique. The composite silicone block was sectioned along a predetermined vertical plane and then incisor slices were analysed through an image analyser.

Santoro et al. (2003) found a significant difference between two groups of plaster and digital models in the measurement of overbite. Other researchers used cephalometric radiographs for overbite measurement (Hans, 2006). In epidemiological studies, prevalence of malocclusion was determined based on the measurement of the mandibular incisor overlap in direct measurements on the subjects (Bezroukov et al., 1979; Onyeaso, 2004; Borzabadi-Farahani et al., 2009).

The normal overbite value determination varied widely in different studies. For example, Tschill et al. (1997) considered the normal overbite to be 3 mm while Thilander et al. (2001) considered normal overbite as 4 mm and Jonsson et al. (2007) found the normal range to be within less than 5 mm. The primary study of occlusal trait defined normal overbite in terms of vertical overlapping of the maxillary and mandibular incisors whereby one third overlap of the crown in the heights of the mandibular incisors were observed (Bezroukov et al., 1979). This vertical overlapping category was later used by other researchers to describe normal overbite, while a measurement of $\geq$ 2/3 overlapping was categorised as deep overbite (Diagne et al., 1993; Behbehani et al., 2005). Table 2.7 below summarised findings of studies on deep overbite.

Table 2.7: Summary of studies on prevalence of deep overbite

Authors (year)	Population	Subjects		Deep overbite	
		N	Age (years)	%	Measurement category
Mŭniz (1986)	Caucasian	1554	12 - 13.	11.6	≥ 2/3 overlap
	Amerindian			5.8	
Diagne et al. (1993)	Senegalese	1708	11 - 19.	4.7	≥ 2/3 overlap
Tang (1994)	Chinese	201	20 mean	4	> 2/3 overlap
Tschill et al. (1997)	French	789	4 - 6.	1.6	> 3 mm
Thilander et al. (2001)	Colombian	1441	13 - 17	19.2	> 4 mm
Onyeaso (2004)	Nigerian	636	12 - 17.	14.1	> 2/3 overlap
Behbehani et al. (2005)	Kuwaiti	1299	13 - 14.	22	≥ 2/3 overlap
Jonsson et al. (2007)	Icelandic	829	31 - 44	13	≥ 5 mm male
				10.7	≥ 5 mm female
Gelgör et al. (2007)	Turkish	2329	12 - 17.	18.3	> 2/3 overlap
Lux et al. (2009)	Garman	494	9	3.6	mean of male
				3	mean of female
Mtaya et al. (2009)	Tanzanian	1601	12 - 14.	0.9	≥ 5 mm
Borzabadi-Farahani et al. (2009)	Iranian	502	11 - 14.	34.5	≥ 1/3 overlap

2.3.4.2 Openbite

Openbite refers to a condition in which the incisal edges of maxillary and mandibular anterior teeth do not overlap (anterior openbite), or no vertical contact is exhibited between maxillary and mandibular posterior teeth (posterior openbite) (Rani, 2001). The prevalence of anterior openbite is more frequent than posterior openbite. Anterior openbite is a difficult problem to treat and in some patients may require a combined orthodontic - surgical treatment. Depending on the cause, openbite is classified as dental or skeletal (Staley, 2001).

Many investigators diagnosed openbite when there was a presence of vertical space in between the maxillary and mandibular teeth with the teeth in centric occlusion (Onyeaso, 2004; Gelgör et al., 2007; Borzabadi-Farahani et al., 2009). While others considered an edge to edge relationship to be an openbite (Al-Emran et al., 1990; Mtaya et al., 2009). The prevalence of openbite in the permanent dentition among populations had been reported within a range of 1.6 to 9% which varied significantly according to race. Table 2.8 summarised findings from studies on anterior and posterior openbite.

Table 2.8: Summary of studies on prevalence of anterior and posterior openbite

Authors (year)	Population	Subjects		Anterior openbite (%)	Posterior openbite (%)
		N	Age (years)		
Lavelle et al. (1976)	British	1330	15 - 20	8.4	0.4
Ingervall et al. (1978)	Swedish	389	21 - 54	3.7	2.2
Al-Emran et al. (1990)	Saudi Arabian	500	14	6.6	0.6
Tschill et al. (1997)	French	789	4 - 6	37.4	
Thilander et al. (2001)	Colombian	1441	13 - 17	9.0	
Lauc et al. (2003)	Croatian	224	7 - 14	3.1	
Tausche et al. (2004)	Garman	1975	6 - 8	17.7	
Onyeaso (2004)	Nigerian	636	12 - 17	7.1	
Behbehani et al. (2005)	Kuwaiti	1299	13 - 14	3.4	
Abu Alhaija et al. (2005a)	Jordanian	1003	13 - 15	2.9	
Gábris et al. (2006)	Hungarian	483	16 - 18	8.9	Unilateral 1.0, Bilateral 0.8
Gelgör et al. (2007)	Turkish	2329	12 - 17	8.2	
Jonsson et al. (2007)	Icelandic	829	31 - 44	2.5	
Mtaya et al. (2009)	Tanzanian	1601	12 - 14	15.0	1.1

2.3.5 Occlusal Discrepancies in Transversal Relationship

2.3.5.1 Posterior Crossbite and Scissor bite

Posterior crossbite is considered as buccal crossbite when the buccal cusp of the maxillary tooth occluded lingual to the maximum height of the buccal cusp of the opposing mandibular tooth. Scissor bite (lingual crossbite) is recorded when the palatal cusp of the maxillary tooth occluded buccal to the maximum height of the buccal cusp of the opposing mandibular tooth (Baume et al., 1973). Thus, posterior crossbite and bite are measured either on sides of the arch segments (bilateral) or in one side of the arch segment either right or left side (unilateral) (Bezroukov et al., 1979).

Epidemiological information available showed that the prevalence of posterior crossbite in the permanent dentition varied between 5 to 25% (Thilander et al., 2001; Behbehani et al., 2005; Borzabadi-Farahani et al., 2009). Other studies reported the prevalence rates of scissor bite in the permanent dentition of the population stated to be from 0.3 to 3% (Al-Emran et al., 1990; Abu Alhaija et al., 2005a). Results from studies on posterior crossbite and scissor bite are as summarised in Table 2.9.

Early orthodontic treatment had shown improvement on the patients' aesthetic with respect to its cost and benefit ratio (Thilander et al., 1984; King and Brudvik, 2010). In the case of crossbite cases, it was recommended that treatment started early because spontaneous correction was unusual.

Table 2.9: Summary of studies on prevalence of posterior crossbite and scissor bite

Authors (year)	Population	Subjects		Posterior Crossbite (%)				Scissor bite (%)
		N	Age (years)	Bi lateral	Uni lateral right	Uni lateral left	Total	
Krzypow et al. (1975)	Israeli	538	18-20				11.0	
Můniz (1986)	Caucasian	1554	12 - 13	0.8				
	Amerindian			0.9				
Al-Emran et al. (1990)	Saudi Arabian	500	14				7.2	3.2
Diagne et al. (1993)	Senegalese	1708	11 - 19	2.4				1.0
Thilander et al. (2001)	Colombian	1441	13 - 17	1.1	3.5		4.6	1.3
Lauc et al. (2003)	Croatian	224	7 - 14		8.9	10.7		0.8
Tausche et al. (2004)	Garman	1975	6 - 8		4.7	3.0		0.5
Abu Alhaija et al. (2005a)	Jordanian	1003	13 - 15				6.8	0.3
Behbehani et al. (2005)	Kuwaiti	1299	13 - 14	6.3	18.9		25.2	
Gábris et al. (2006)	Hungarian	483	16-18	0	7.9		7.9	
Jonsson et al. (2007)	Icelandic	829	31 - 44				24.6	3.1
Gelgör et al. (2007)	Turkish	2329	12 - 17	4	3.3	2.2	9.5	0.3
Lux et al. (2009)	Germany	494	9	1.2	10.6		11.8	0.2
Borzabadi-Farahani et al. (2009)	Iranian	502	11 - 14	2.0	4.6	3.8	10.4	2.0
Mtaya et al. (2009)	Tanzanian	1601	12 - 14				5.1	14.3
Perillo et al. (2010)	Italian	703	12				14.2	

2.4 Methods of Malocclusion Measurements

Malocclusion has proven to be a difficult entity to define because individual perceptions of what constitutes a malocclusion problem differ widely. As a result, no general accepted epidemiological method for measuring malocclusion has been devised (Striffler et al., 1983). Consequently, choosing a good method to record or measure malocclusion is vital and valuable for the prevalence and severity documentation of

malocclusion in a population. This kind of data is not only important for the epidemiologist, but also for those who plan for the provision of orthodontic treatment in a community or for the training of orthodontic specialists (McGuinness and Stephens, 1994).

2.4.1 Requirements of an Ideal Method for Malocclusion Measurement

An objective method of measuring and recording deviations that may constitute a malocclusion is of vital importance in epidemiology to permit assessment between populations in terms of prevalence and severity of these alterations. Due to substantial diversity of recording methods of measuring malocclusion, strict requirements were imposed for an index of malocclusion (Tang and Wei, 1993). The requirements for any index of occlusion are:

- Measurements of malocclusion in a finite range with an upper and a lower severity, expressed by a single number. The scale should be progressively graded from zero (no disease) to ultimate point in its terminal stage disease.
- The index should appear equally sensitive at all points of the scale, with corresponding to disease stage.
- Index value has to be adaptable to statistical software and analysis.
- The index should be reproducible and requisite instruments in an actual field situation.
- The index should be flexible enough to permit the study of a large population without undue cost in time or energy, with a minimum of judgment.
- The index should allow the cases to shift in the better or to the worst condition.
- Validity during time also an important requirement for any index.

These requirements were summarised in a World Health Organisation Report (WHO 1966) as points 1 to 6. Summers (1971) later added point 7 to the list and explained the validity during that time.

Similarly, Shaw and co-workers (1991) recommended the following properties for measuring malocclusion in a population.

- Adequate to profession and community.
- Responsive to patient need.
- Simple to manager.
- Sensitive throughout the scale.
- Reliability of an occluasl index requires that repetitions of measurements by one or more than one examiner must be producing the same results.
- Validity of an occlusal index is established by comparing the results of group orthodontists; however, the index should be sensitive to occlusal traits and the information obtained usually are the same.
- Amenable to statistic analysis.
- Minimum equipment and instrumentation required.
- Capable to identify a shift in group conditions.

2.4.2 Classification of Malocclusion Assessment Methods

Tang and Wie (1993) divided the methods of recording and measuring malocclusion generally into qualitative and quantitative assessment. The qualitative assessment of malocclusion was a descriptive method; therefore, this category included the diagnostic classification. Historically, qualitative analysis was developed earlier than quantitative analysis. The main weakness of qualitative method is that malocclusion was a

continuous variable so that clear cut-off points were not present between different categories of malocclusion (Mitchell, 2001).

In the earlier qualitative measurement methods, only a few malocclusion traits were recorded (Sclare, 1945). In the later methods, there was an increasingly obvious tendency to record items that were logically grouped (Björk et al., 1964; Proffit and Ackerman, 1973). The Angle Classification method (1899) was one of the well-known qualitative methods. However, other classification methods were now more widely used, such as the 1983 British Standards Institute Classification of incisor relationship (Mitchell, 2001).

The quantitative methods of measuring malocclusion were developed somewhat later than those for qualitative methods. The main improvement in quantitative methods was the identification of cut-off points between different continuous variables of malocclusion. Massler and Frankel (1951) made the initial step to develop a quantitative method of measuring malocclusion. The total number of displaced or rotated teeth was the base for the estimation of malocclusion prevalence and incidence among population study sample. After that, Van Kirk and Pennell (1959) proposed the Malalignment Index, which involved the grading of tooth displacement and rotation. In addition, in 1967, Grainger developed the treatment priority index as an epidemiologic measuring tool to rank malocclusion and priority of treatment.

However, at the present time, the most often used quantitative assessment methods are those recording the worst feature of a malocclusion. One example is the Index of Orthodontic Treatment Need (IOTN) (Mitchell, 2001).

Shaw et al. (1991) classified methods of malocclusion measurement according to the method target and outcome as follows:

1. Diagnostic Classification provided enough description of malocclusion which allows communication among clinicians, e.g. Angle classification and Incisor classification.
2. Epidemiological data collections indices were developed to describe the parameters and prevalence of occlusal traits within a population. Examples were;

   (a) The Epidemiologic Registration of Malocclusion (Björk et al., 1964).

   (b) Occlusal Index (Summers, 1971).

   (c) FDI method of recording occlusal traits (Baume et al., 1973).
3. Treatment Needs / Priority Indices assessed the need for treatment in a population so that priority could be assigned to selected cases when resources are limited. Examples were;

   (a) The Handicapping Labio-lingual Deviations Index (Draker, 1960).

   (b) Treatment Priority Index (Grainger, 1967).

   (c) Handicapping Malocclusion Assessment Record (Salzmann, 1968).

   (d) Dental Aesthetic Index (Cons et al., 1986).

   (e) The Index of Orthodontic Treatment Need (Brook and Shaw, 1989).
4. Treatment Outcome Indices compare pre and post treatment records and registered the outcome of orthodontic treatment, Eismann (1974) and Peer Assessment Rating Index (Richmond et al., 1992b).

On the other hand, there are also other groups of measurement methods:

- Treatment Complexity; treatment difficulty was related to the aetiology of occlusal irregularity rather than to the irregularities themselves. A complexity index tried to classify cases according to the level of operator competence needed to provide quality care, e.g. Index of Complexity Outcome and Need (Daniels and Richmond, 2000).

- Aesthetic Need was developed in response to scientific surveys highlighting the importance of aesthetic impairment on a patient's psychological well-being, e.g. SCAN Index of Standardised Continuum of Aesthetic Need (Evans and Shaw 1987).

2.4.3 Evolution of Malocclusion Classifications and Indices

Angle Classification, the main method of occlusal assessment, was used in orthodontic diagnosis. However, indices had long been used to categorise medical and dental disorders for the purposes of epidemiological research, and to allocate patients into treatment need categories (McGuinness and Stephens, 1994). Short reviews of the most important methods registration of malocclusion are listed in chronological order as below.

2.4.3.1 Angle Classification (1899)

In orthodontics, the classification of malocclusion plays several significant roles. First, classification is used in the diagnosis of malocclusion by orthodontist to determine the severity and types of malocclusion. Second, classification facilitates communication between specialists, and in this regard all orthodontists speak the same language for communication in diagnosis as stated by Katz (1992a).

Angle Classification of malocclusion (first published in 1899) considered the maxillary permanent first molars and maxillary permanent canines as important teeth from which to judge the mesiodistal interarch relationship of dental arches. Angle also believed that all the teeth should be considered when determining the classification of malocclusion. However, Angle assumed that upper first molars were the key to occlusions, and that the upper and lower molars should be related so that the mesiobuccal cusp of the upper molar occluded in the mesiobuccal groove of the lower molar. In addition, he also

believed that the upper and lower first molars should be the basis of diagnosis in orthodontics. The first molars are very important because they are the largest teeth in the arch, firmest in their attachment, position at key location in the arches and also most consistent in terms of eruption timing as well as determinant of the dental and skeletal vertical height.

2.4.3.1.1 Criticisms of Angle Classification

Angle Classification had been recognised as being simple and widely used in orthodontic diagnosis; however numerous studies had also questioned its validity and usefulness.

Rinchuse and Rinchuse (1989) published a paper which described the limitation of Angle Classification as a system of discrete classes. In fact, Angle admitted that his classification system did not address all possible malocclusion types, such as the case where one side was Class II and the other was Class III. Thus, the validity of Angle Classification had been challenged because it only addressed the antero-posterior dental dimension; whereas it did not address the vertical and transverse dental dimension.

Pickering and Vig (1975) mentioned that Angle Classification was meaningless because it did not indicate disabilities in dental health, function or aesthetics. Furthermore, the reliability of Angle Classification was also questioned by Gravelt and Johnson (1974). They demonstrated poor intra and inter-examiners reliability when using Angle Classification, especially in Class II division 2 malocclusion.

Du et al. (1998) in their study measured the reliability of three methods of occlusion namely Angle Classification, modified Angle Classification and British incisor classification. In this study four orthodontists with at least 20 years of experience measured twenty five atypical dental casts. Their results found that Modification of

Angle Classification was more reliable, and the traditional Angle Classification was found to be the least reliable of the three methods.

Katz (1992b) however, mentioned that it would be easy to send Angle Classification away as past and developed classification to represent the cutting edge of recent thinking. This is difficult to accept as Dr-Angle is one of the orthodontists who are most seminal thinkers, and then every dental student had learned that Angle mesiobuccal cusp of the upper first molar fits into the buccal groove of the lower first molar truism by rote.

Sarver et al. (2000) reported that the reason why Angle system had remained the most accepted method of classifying malocclusions for nearly a century was in part due to its simplicity, also partly due to the fact that many of the malocclusion referred by orthodontists included an antero-posterior problem. Angle Classification had also long been accepted and adopted by the American Board of Orthodontics (ABO) in its Phase III examination. In addition, the Angle taxonomy had remained to be a vehicle for describing cases among orthodontists as well as other dentists. It had also remained to be the language accepted by the legal profession to describe case reports and epidemiological studies (Du et al., 1998; Snyder and Jerrold, 2007).

Siegel (2002) highlighted that confusion existed in the orthodontic community regarding the meaning of the subdivision in Angle Classification system. He reported that the orthodontic community did not have a consistent standard and therefore it was a time to resolve this controversy.

2.4.3.1.2 Modifications of Angle Classification

A recent study by Synder and Jerrold (2007) recommended that the Angle method should not be replaced, instead it could be modified so as to be universally accepted. In addition, it had withstood the test of time because of its simplicity and the fact that it was already entrenched in the specialty which would take a revolution to replace it.

Katz (1992b) presented an option to the modification of Angle Classification. The designated ideal cusp-embrasure occlusion (as described by Angle) was termed as zero (0). A plus sign (+) designated a Class II direction and a minus sign (-) designated a Class III tendency. In his study the ideal occlusion on both sides (right and left) was termed as (0,0).

Thus, if a patient measured as having an ideal occlusion on the right side but a 2 mm Class II on the left side, the modified classification would be reported as (0 , +2). On the other hand, if another patient presented half a cusp Class II (cusp-to-cusp occlusion) on the right side and a full cusp Class II on the left side, the modified classification would be termed as (+4 , +8). A third patient who had a 1.5 mm Class II on the right and 3.5 mm a Class III on the left side would be classified as (+1.5 , -3.5). In this study the right side was reported first then the left side. This Modified Angle Classification by Katz (1992b) had a number of beneficial features when compared to other classifications as follows;

1. Modified system establishes cusp-embrasure point rather than a range of 7 mm (half of a cusp each way) as in the traditional Angle Classification.
2. Supplemental classification quantifies the degree of malocclusion accurately in millimetres and for each side independently.

3. This method permits the orthodontists to classify their patients who have asymmetrical malocclusion classes for example, Class II on one side and Class III on the other side.
4. This numerical system allows computer input to the severity malocclusion to be rated and compared effortlessly for statistical and research purposes.
5. This new system assist early treatment analysis for deciduous and mixed dentition.

Du et al. (1998) in their classic critique of reliability identified that Katz's Modification of the Angle Classification appeared to be more valuable for research because of its incessant and quantifiable nature. However, it might also be ideal for epidemiologic research and had more reliable diagnostic phases. The latter view was supported by Brin et al. (1999). They reported that the modified Angle Classification might serve as a useful complement to the classical Angle method and the features incorporated in this modified method made it more appropriate for teaching purposes, namely a classification adjunct.

Pair et al. (2001) used a Modified Angle system in their study. They defined the 'grey' area and limited Class I to a single point. However, unlike Katz's system which defined deviations away from ideal Class I in millimetres, they chose a more practical system that allowed visual measurement without the need of a ruler. In addition, choices were also given by adding one quarter, one half, three quarter, and full cusp. These changes allowed the practitioner possibility of classifying a patient into 9 categories. This was more representative in a continuum of possibility. The high reliability and reasonable accuracy that the modified Angle Classification was rigid enough to define the grey area and therefore could be a practical mean of standardising occlusion classification. Snyder and Jerrold (2007) in their study, proposed a Modification of Angle

Classification similar to what Pair et al. (2001) used. However, they designated ¼ cusps, ½ cusp, and ¾ cusps discrepancies with the letters A, B, and C, respectively.

The prevalence of malocclusion in the general population had been reported using Angle measurement to vary greatly according to geographical location and races. Table 2.10 showed a summary of studies on the prevalence of malocclusion according to Angle class's assessment.

Table 2.10: Summary of epidemiological studies on malocclusion according to Angle classes assessment

Authors (year)	Population	Subjects		Occlusion measurement			
		N	Age (years)	Normal	Malocclusion		
					Class I	Class II	Class III
Krzypow et al. (1975) (A)	Israeli	538	18-20	4.1	65.2	28.1	2.6
Isiekwe (1983) (A)	Nigerian	617	10-19		76.8	14.7	8.4
Garner and Butt (1985) (A)	Kenyan	505	13-14	16.8	51.7	7.9	16.8
	Black Americans	445	13-15	27.0	44.0	16.0	8.7
Kerosuo et al. (1988) (A)	Tanzanian urban	642	11-18		96.0	3.0	1.0
Al-Emran et al. (1990) (A)	Saudi Arabian	500	14			16.4	3.0
Diagne et al. (1993) (A)	Senegalese	1708	11-19		73.3	12.7	4.4
Tang (1994) (M)	Chinese	201	20 mean		63.7	16.4	19.9
Thilander et al. (2001) (A)	Colombian	1441	13-17			20.8	3.7
Lauc et al. (2003) (M)	Croatian	224	7-14		47.3	45.1	5.4
Onyeaso (2004) (A)	Nigerian	636	12-17	24.0	50.0	14.0	12.0
Abu Alhaija et al. (2005a) (M)	Jordanian	1003	13-15		79.8	18.8	1.4
Behbehani et al. (2005) (M)	Kuwaiti	1299	13-14		57.8	31.2	11.0
Behbehani et al. (2005) (C)					36.1	56.2	7.7

Continued Table 2.10

Gelgör et al. (2007) [A]	Turkish	2329	12-17	10.1	34.9	44.7	10.3
Borzabadi-Farahani et al. (2009) [A]	Iranian	502	11-14	22.9	41.8	27.5	7.8
Mtaya et al. (2009) [M]	Tanzanian	1601	12-14		93.6	4.4	2.0
Martins and Lima (2009) [A]	Brazilian	264	10-12	25.8	47.7	22.3	4.2

[M] Measurement based on molar relationship, [C] Measurement based on canine relationship, [A] Measurement based on occlusion relationship.

2.4.3.2 Massler and Frankel (1951)

Massler and Frankel (1951) suggested a quantitative method of assessing malocclusion for epidemiological purposes. In this method the individual tooth was considered as a unit of occlusion. Each tooth was examined twice and from two different aspects. The first aspect examined the occlusal surface of the jaws apart, and the second aspect examined the buccal and labial surfaces of the teeth. A tooth position could be one of three; correct position, malposition or missing.

A score was given to the individual depending on the number of malposed teeth. However, in this method it was difficult to judge the tooth position in all planes of space which causes mismeasurement in scoring as reported by Poulton and Aaronson (1961).

2.4.3.3 Malalignment Index (1959)

Van Kirk and Pennell (1959) proposed an index for assessing malocclusion based on the registration of dental malposition. This index provided scoring for the departure of each tooth from its ideal position and summing-up of scores were recorded for six segments; maxillary anterior, maxillary right posterior, maxillary left posterior, mandibular anterior, mandibular right posterior and mandibular left posterior. The

values were summed to give a score for each segment. The final score gave the malalignment index as the sum of the scores recorded for all these six segments. A small plastic gauge-like tool was designed to make the required measurements of displacement and rotation of each tooth from the ideal arch line. Each tooth was scored 0, 1 or 2.

Score 0: Represents ideal alignment.

Score 1: Represents minor malalignment, where tooth displacement is less than 1.5 mm and tooth rotation that presented in the ideal arch line is less than 45degrees.

Score 2: Represents major malalignment in which the displacement is 1.5mm or more and observed tooth rotation is present in the ideal arch line is 45 degrees or more.

In using this index, the measurements were recorded with the mouth opened. The alignment was evaluated only from occlusal aspects and did not include the relationship of the upper and lower arches.

2.4.3.4 Handicapping Labio-lingual Deviations Index, HLDI (1960)

Draker (1960) introduced the HLDI and designed it to measure occlusal factors that caused disfigurement and to measure the degree of orthodontic handicap. This index avoided classifying malocclusion and concentrated on the aim of confirming the presence or absence of an orthodontic handicap. The index was based on nine conditions; cleft palates, severe traumatic deviations, overjet, overbite, mandibular protrusion, openbite, ectopic eruption, anterior crowding of upper and lower teeth and labio-lingual spread. This index introduced the concept of labio-lingual spread of tooth deviation from the normal arch line, as measured by the Boley gauge in millimetre. The measurement was recorded between the incisors edge of the displaced tooth and the normal arch line.

The HLDI was a highly reproducible method for eligible orthodontic treatment with public funds. Modifications of the HLDI rely on morphological deviations from the norm. Public health programs in America have adopted several modifications with subjective cut-off scores to determine treatment need in different states. Maryland modified the HLDI by increasing the cut-off points from 13 to 15 points. In 1998, Parker modified the HLDI and called it CalMod, which was used to estimate treatment need within the state program in California. This modification was composed from the previous nine components and deep impinging overbite, crossbite of individual anterior teeth and posterior crossbite. These measurements were weighted and then summed to give a score.

Reliability and validity of the HLDI was reported by Younis et al. (1997) and Beglin et al. (2001). In 2005, Theis and his co-workers used Washington State HLD Modified Index in their study of treatment priority. They reported that HLDI was a useful tool to use for determining medicaid eligibility for publicly funded orthodontic treatment. Recently, Jolley et al. (2010) in their longitudinal study also used HLDI to evaluate medicaid eligibility and the changes after interceptive treatment on children. They found reduced eligibility for medicaid funded orthodontic treatment with early interceptive treatment children.

The recommended cut-off for HLDI was found to have good specificity but very poor sensitivity. A possible reason for poor sensitivity was probably because the cut point of index derived by authors or public policy decision. This cut point was without the benefit of a validation process (Younis et al., 1997).

2.4.3.5 Malocclusion Severity Estimate, MSE (1961)

The Malocclusion Severity Estimate was developed at the Burlington Orthodontic Research Centre by Grainger (1961). This index could be used either on study models or direct on patients. Validity was tested by comparing the index scores of a study sample with clinical standards obtained by five orthodontists and one public health dentist. The latter array this occlusion according to aesthetic, function and treatment difficulty. The index composed of seven measurements; overjet, overbite, anterior openbite, congenitally missing maxillary incisors, fist permanent molar relationship, posterior crossbite and tooth displacements. The index was found to be highly reproducible.

Unfortunately, scores gained by using MSE index did not represent all the measurements that were accumulated, and also, any occlusal disorder absence was not scored as zero. These points were considered as the shortcomings of MSE (Gray and Demirjian, 1977). In 1967, Grainger modified the MSE to develop the Treatment Priority Index (TPI).

2.4.3.6 Occlusal Feature Index, OFI (1961)

This index was proposed by Poulton and Aaronson (1961). It was based on four primary features of occlusion which were important in an orthodontic examination.

1) Lower anterior arch crowding in the canine to canine area.
2) Cuspal interdigitation, in the right premolar to molar area.
3) Vertical overbite, measured by that position of the lower incisors covered by upper central incisors in occlusion.
4) Horizontal overjet measured in occlusion with a small ruler from the labial surface of the upper incisors to labial surface of lower incisors.

The number for each score of the four categories was recorded in 908 subjects and a total score was obtained by adding them together. In addition, periodontal status was also taken and a significant correlation was found with malocclusion.

The OFI was found to be highly reproducible in evaluating the relationship between malocclusion (such as crowding, overjet and overbite) and periodontal health (Katz, 1978 and Bollen, 2008).

2.4.3.7 Method for Epidemiological Registration of Malocclusion, MERM (1964)

Björk et al. (1964) introduced a method for the objective registration of malocclusion symptoms based on detailed definitions. This comprehensive system was developed for epidemiological purpose with major deviation from normality. It was used by many investigators (Al-Emran et al., 1990; Thilander et al., 2001; Jonsson et al., 2007). The registration of malocclusion was divided into three parts:

(a) Anomalies in the dentition; these include supernumerary teeth, aplasia, malformation, ectopic eruption, hindered eruption, arrested eruption, transposition, persistent deciduous teeth, rotated teeth, inversion of incisors and tipping.

(b) Occlusal anomalies; these include deviation in the positional relationship between the maxillary and mandibular arches. The occlusion is divided into sagittal, vertical and transverse.

(c) Deviation in space conditions; this part includes spacing or crowding of teeth which is recorded in two separate sections, one for incisors and the other to include canines and premolars.

This method also included the registration of other supplementary data such as midline displacement, maxillary diastema and abnormal maxillary frenum. A special metallic instrument was designed to measure dimensions and angles.

2.4.3.8 Treatment Priority Index, TPI (1967)

This index was developed by Grainger (1967). He described the index as an epidemiological tool used to rank malocclusion and priority of treatment. As mentioned earlier, the TPI was developed and modified from the Malocclusion Severity Estimate (MSE). The following ten features of occlusion were recorded; Overjet, reversed overjet, overbite, openbite, congenitally absence of incisors, disto- and mesio- molar relation, posterior crossbite (buccal and lingual) and tooth displacement.

Grainger grouped the occlusal features that tend to occur together calling them syndromes and determined a weighting for each syndrome. The prerequisites for determining a handicap were defined as follows: 1) unacceptable aesthetics 2) significant reduction in masticatory function 3) traumatic conditions predispose to tissue destruction 4) speech impairment 5) unstable occlusion and 6) gross or traumatic defects. On the basis of these six prerequisites for determining a handicap, items to be observed in the TPI were selected.

This index scored normal occlusion as zero, occlusal features were ranked from one to ten (Table 2.11) according to the severity of malocclusion and the degree of treatment priority

Table 2.11: Severity and treatment priority of malocclusion according to TPI

Occlusal feature score	Malocclusion severity	Treatment need priority
0	Normal occlusion	No
1-3	Minor	Slight
4-6	Definite	Elective
7-9	Severe	Highly desirable
10	Very severe	Mandatory

Treatment Priority Index was proven to be an efficient epidemiological method of malocclusion without undue cost and energy (Slakter et al., 1980). It was highly reproducible (Gray and Demirjian, 1977). It had been used on study models (Katz, 1978) and intra-orally (Ugur et al., 1998).

This index was found to be a valid malocclusion measurement method but did not predict the future severity of malocclusion in the permanent dentition (Ghafari et al., 1989). Further inspection of the TPI revealed the weakness of the index in that the distal and mesial molar relations were considered equal. In addition, a few manifestations of malocclusion such as maxillary diastema were also not measured.

2.4.3.9 Handicapping Malocclusion Assessment Record, HMAR (1968)

In 1967, Salzmann defined and assessed malocclusion records without the use of millimetre measurements to determine a handicapping malocclusion in the permanent dentition. In 1968, he established the cut-off points and priority treatment need of handicapping malocclusions. Handicapping malocclusion and handicapping dento-facial deformity were defined as conditions that constituted a hazard to the maintenance of oral health and interfered with the well-being of the child, by adversely affecting dento-facial aesthetic, mandibular function or speech. In this assessment, scores were given to every case and the priority for treatment was given to cases with the highest scores in decreasing order and a cut-off point was set according to the availability of professional personnel and funds. The scores of the analysis could be obtained from both study models and direct examination on the patients.

In 1970, Allen examined 110 children using HMAR Method. He reported that a valid epidemiologic method for malocclusion in assessing children for third-party orthodontic care programs, especially in intra-oral examination. Otuyemi and Noar (1996a) later

tested the reproducibility of HMAR on 30 sets of pre-treatment study models of children aged between 11-16 years. Intra and inter-examiners reproducibility were found to be high (0.82-0.96) but was significantly lower than that of the Dental Aesthetic Index (DAI).

The scoring of handicapping was divided into three parts.

1) Intra arch deviations; missing teeth, crowded teeth, rotated teeth, open spacing "crest of interdentally papilla is visible" and closed spacing "space insufficient for completion of eruption of partially erupted teeth.
2) Inter arch deviation; overjet, overbite, openbite, crossbite and mesiodistal deviation.
3) Dento-facial deformities; clefts, lower lip palatal to maxillary incisors, occlusal interference, functional jaw limitation, facial jaw limitation, facial asymmetry and speech impairment.

The HMAR method was approved by the American Dental Association and the American Association of Orthodontists for evaluating malocclusion and setting priority for dealing with bad occlusion.

2.4.3.10 Occlusal Index (1971)

Occlusal Index was developed in 1966 and published in 1971 by Summers to measure occlusal features in determining priorities of treatment need of a population. This index was designed to establish whether or not orthodontic treatment was needed. It had the advantage that it can be used either on study models or directly on the patient. It could also be used in all phases of teeth development. The method scored nine characteristics of occlusal index; Dental age, molar relation, overbite, overjet, posterior crossbite, posterior openbite, tooth displacement (actual and potential), midline relations and

missing permanent teeth. After obtaining the overall score, malocclusion was described into five categories:

1) Good occlusions: No occlusal discrepancy.
2) Slight deviation of occlusion: No need treatment.
3) Minor malocclusion: Simple treatment (space maintainers or removable appliances).
4) Major deviations in the occlusion: Definite treatment (treatment which would include banding of many teeth).
5) Worst occlusion: The patient rank first in treatment priority.

This method was later used by many investigators (Elderton and Clark, 1983; Tang and So, 1995; Arruda 2008). The shortcoming of the Occlusal Index was in that more time needed to score for malocclusion (So and Tang, 1993). In addition, the bucco-lingual tipping and missing teeth, except for maxillary permanent incisors, were not scored (Tang and So, 1995).

2.4.3.11 Method for Measuring Occlusal Traits, (FDI, 1973)

The index for measuring occlusal traits was developed by the Fédération Dentaire Internationale (FDI) Commission on Classification and Statistics for Oral Conditions (COCSTOC) (Baume et al., 1973). The aim of this method was to present a fairly simple objective method of measuring occlusal traits. Prior to the above, a basic method was developed during the years 1969 to 1972 by the Working Group 2 (WG2) of the FDI to record individual traits of malocclusion. Before deciding on the treatment need method, group had to come to an agreement to what individual traits of malocclusion to measure (Baume et al., 1973). This method measured the permanent dentition in three parts namely;

- Dental measurements or dental discrepancies: Including anomalies of development (congenitally missing, supernumerary, malformed and impacted teeth), missing teeth due to extraction or trauma and retained primary teeth.
- Intra-arch measurements or space discrepancies: Including crowding, spacing, anterior irregularities and maxillary central diastema.
- Inter-arch measurements or occlusal discrepancies: Lateral segments (antero-posterior, vertical and transversal relation) and incisal segments (overjet, overbite, midline deviation and soft tissue impingement).

The Fédération Dentaire Internationale (FDI) method was field tested between 1973 - 1976 and modified by members of WG2. The new version entitled 'Basic method for recording occlusal traits' presented the results of the collaborative work between the World Health Organisation (WHO) and the FDI, and proposed the recording to be called the FDI/WHO method. The final version of the method was published by Bezroukov et al. (1979) after it was modified. The main objective of the modified method was to establish prevalence of malocclusion and estimate the need for treatment. The modified method also included different levels of malocclusion severity, such as anterior crossbite (classified into 1 tooth to 3 teeth), and maxillary overjet (grouped into < 6 mm, 6 mm to < 9 mm and ≥ 9 mm). The indications for treatment were scored into four categories: treatment not necessary, doubtful, necessary and urgent.

This method was an objective and comprehensive system developed for epidemiological purposes which attempted to determine the most common malocclusion traits. It had been widely used in many countries (Mũniz 1986; Diagne et al., 1993; Tschill et al., 1997; Tod and Taveme, 1997; Ciger and Akan, 2010). FDI/WHO method falls in deficient when used a subjective evaluation for treatment need.

2.4.3.12 Swedish Public Health Index (1974)

This index of treatment need requirements was intended more as a basic guide in decision making on whether the patient need or did not need treatment. It was very useful in public orthodontic services especially when resources were limited.

A priority component of the index for orthodontic treatment need was drawn up by the orthodontic section of the Swedish Dental Society and the Swedish Medical Board (1966) and was later elaborated by Linder-Aronson (1974). This index used a scale that classified patients into four possible categories according to their need for orthodontic treatment, from 'little or no need' to 'very urgent need' as follows:

Grade 4: Handicapping anomalies such as cleft lip and palate, extreme Class II or Class III occlusion, retained upper incisors and extensive aplasia.

Grade 3: Pre normal forced bite, deepbite with gingival irritation, extremely openbite, crossbite, causing transverse forced bite, scissor bite interfering with articulation, severe frontal crowding or spacing, retained canines, cosmetically and/or functionally disturbing rotations.

Grade 2: Aesthetic and/or functionally disturbing proclined or retroclined incisors, deep bite with gingival contact but without gingival irritation, severe crowding or spacing of teeth, infraocclusion of deciduas molars and permanent teeth and moderate frontal rotation.

Grade 1: mild deviation from ideal occlusion

In their study, Linder-Aronson (1974) found that 11% of all the children in the age groups 7-16 years needed treatment. In addition, the average treatment time was found to be 4.2 hours per patient per year. This index was recommended to be used in treating extreme disabling malocclusion. It was later modified and incorporated into the Index of Orthodontic Treatment Need (Brook and Shaw, 1989).

2.4.3.13 Eismann Index (1974)

Eismann (1974) in Germany developed a quantitative and objective method for malocclusion measurements and evaluation of the efficacy of orthodontic treatment. Measurements were made from plaster casts at the beginning and end of treatment. The Eismann index was based on numerical evaluation of fifteen morphological traits of malocclusion. The allocation of point values was based on the author's estimate of the need for treatment; aesthetics, function and the possible consequence of the untreated anomaly on general dental health. The point values for each of the fifteen traits were added together to give a total.

Farčnik et al. (1985, 1988) modified Eismann's method, by adding the numerical assessments on improper orofacial functions; mouth breathing, atypical swallowing and bad atypical sucking habits. The modified Eismann index was used by Slovenian public health care system to determine the level of a third-party payment, undergraduate students and training specialists. Ovsenik and Primožič (2007) in their study concluded that the Eismann index and Eismann-Farčnik method were valid and reliable for assessing malocclusion severity. However, the latter method needed more calculations and was found to be time consuming.

2.4.3.14 Indication Index (1977)

This index introduced by Lundström (1977) evaluated the discrepancies of malocclusions namely;

(1) Aesthetic / Psychosocial.

(2) Prophylactic, which included; plaque retention, gingival impingement, cranio-mandibular disorders, root resorption and traumatic injury.

(3) Functional, which included; mastication deficiency, speech defects and mouth breathing.

The actual or expected discrepancies of malocclusions were estimated and marked in one of three columns for very great, great or moderate/uncertain disadvantages. The disadvantage for each component was either marked with an 'x' in one of the three columns or left blank if the estimated disadvantage was judged to be little or none. The marks in the different columns were summed up and the total score was expressed as a 3 - digit number.

According to the number of markings in the different columns, the scores were converted to a global scale. The treatment need was then expressed as a number between 0 and 10. The reliability of this index had been tested by Bergström and Halling (1997) and found to be suitable for estimating treatment need.

2.4.3.15 British Standards Institute Classification (1983)

British Standard Incisor Classification was based on the work of Backlund (1958) and introduced by Ballard and Wayman (1965). Backlund studied the relationship of lingual surfaces of upper incisors on which the lower incisors occluded in a Caucasians sample using lateral radiographs. This classification included Angle categories of malocclusion. Williams and Stephens (1992) later conducted a similar study to assess the reproducibility of British Standard Incisor Classification and found it to have moderate to substantial agreement. The most number of disagreements was associated with 'borderline' of Class I and Class III. The disagreement was found to be due to the cingulum plateau rather than the middle third of the visible palatal surface of the maxillary central incisor.

The British Standard Incisor Classification for malocclusion had been widely used for incisor occlusion measurement. This classification had high reliability when compared to Angle Classification since the posterior teeth did not influence the measurement in the Incisor Classification (Du et al., 1998).

2.4.3.16 Severity Index (1986)

Crabb and Rock in 1986 developed a simplified index known as the Severity Index. This index was applied on study models of late mixed dentition age 9 years where thirteen occlusal features were assessed in millimetres as follows:

overjet, overbite, maxillary incisor crowding measured between the distal contact points of the lateral incisors on a curve passing through the incisal edges, mandibular incisor crowding, centre shift, maxillary incisor crossbite, maxillary buccal segment crowding, mandibular buccal segment crowding, molar occlusion (Angle Classification), buccal segment crossbite, malposition, missing/extra teeth and cleft palate.

Every feature was given a score, the sum of which produced the Severity Index. This index did not claim to measure the need for both aesthetic and functional treatment.

2.4.3.17 Dental Aesthetic Index, DAI (1986)

In 1986, Cons and co-workers developed the Dental Aesthetic Index (DAI), which had two components; a functional component and aesthetic component. It linked both clinical and aesthetic components mathematically to produce a single score that combined the physical and the aesthetic aspects of occlusion. It was found to be reliable (Cons et al, 1986) and had been accepted by the WHO as a screening tool.

The public rating of the dental aesthetic was obtained by taking the anatomical measurements available for each stimulus and running regression analysis. This work provided the statistical basis for the regression coefficient weightings used against the 10 occlusal traits below, which yielded the DAI formula:

1) Missing incisors, canine and premolar teeth.
2) Crowding in the incisal segments.
3) Spacing in the incisal segments.

4) Diastema.
5) Largest anterior maxillary irregularity.
6) Largest anterior mandibular irregularity.
7) Anterior maxillary overjet.
8) Anterior mandibular overjet.
9) Vertical anterior open bite.
10) Antero – posterior molar relation.

The DAI regression equation called for the measured components of the index to be multiplied by their regression coefficients (weights), the addition of their products and the addition of a constant number 13 to the total. The resulting sum was the DAI score. The DAI scores were interpreted as follows (Jenny and Cons, 1996):

- Score of 25 and below represented normal or minor malocclusions with no or slight treatment need.
- Score of 26 through 30 represented a definite malocclusion with treatment being elective.
- Score of 31 through 35 represented severe malocclusion with treatment highly desirable.
- Score 36 and higher represented very severe handicapping malocclusions with treatment considered mandatory.

The Dental Aesthetic Index was used by many investigators in different countries including Malaysia (Abdullah and Rock, 2001; Esa et al., 2001), India (Shivakumar et al., 2009; Poonacha et al., 2010) as well as Iran (Danaei and Salehi 2010). The DAI appeared to be simple to use, but the lack of assessment of occlusal traits such as buccal crossbite, buccal openbite, teeth impacted and deepbite weakness of this index (Otuyemi and Noar, 1996b; Danyluk et al., 1999). In addition, the measurements for DAI needed the use of millimetre gauge. It did not have a specific measurement tool,

and small errors in accuracy could have an exaggerated effect because of the index weightings, as stated by Yeh et al. (2000).

2.4.3.18 Index of Orthodontic Treatment Need, IOTN (1989)

The Index of Orthodontic Treatment Need was developed by Brook and Shaw (1989). The index was developed on the rationale that individuals with greatest need for treatment could be assigned priority when orthodontic resources were limited and availability of treatment was unevenly spread. Similarly, individual with little need for treatment could be safeguarded from the potential risks of treatment (Shaw, 1988).

The Index of Orthodontic Treatment Need (IOTN) developed as a result of a government initiative in Great Britain and to help determine the likely impact a malocclusion could take on an individual's dental health and psychosocial well-being (Mitchell, 2001). The orthodontic departments at the Universities of Bristol and Manchester were commissioned to undertake the task of developing an occlusal index to determine priority for orthodontic treatment.

Brook and Shaw (1989) found that the best way to achieve the objectives above was by using two separate components to record malocclusion; objectively to measure the dental health and function indications for treatment (Dental Health Component, DHC), and subjective assessment of aesthetic impairment caused by malocclusion (Aesthetic Component, AC).

The Index of Orthodontic Treatment Need was found to be an easy, pleasant index to be used and demonstrated very good levels of intra-examiner agreement (Holmes, 1992). It had also been accepted by both orthodontists and patients (Beglin et al., 2001). This index has been used widely to evaluate actual and perceptive treatment needs in

different ethnic backgrounds and becoming a more popular measuring tool for malocclusion in the Middle East (Hassan, 2006).

2.4.3.18.1 Dental Health Component (DHC) of IOTN

The Swedish Public Health Index (Linder-Aronson, 1974) was used as the basis for the Dental Health Component grades. Functional and dental health indication for treatment comprised of five grades. Grade 1- No need for treatment, grade 2- Little need, grade 3- Moderate need, grade 4- Great need, and grade 5- Very great need for treatment (Appendix 1). Brook and Shaw (1989) attempted to cut-off values between grades for each occlusal trait that represented a quantifiable trait to the dentition. In actual use, only the highest scoring trait need was recorded. Measurement of crowding in Dental Health Component was recorded based on the largest displacement between teeth in the arches (modified version of index was described by Lau et al. (1984).

Richmond et al. (1992a) carried out a number of investigations pertaining to the conventions for the DHC (Appendix 2). They reported many instances in which the criteria were open to interpretation. The Dental Health Component of IOTN is an objective method of measurement for normative orthodontic treatment need assessment of a population in an attempt to obtain information on treatment priority. The DHC have been used by many investigators in different ethnic groups and populations (Table 2.12).

The index also used the Dental Health Component ruler developed for clinical examination which provided measurement guideline for occlusal traits, as it relates to IOTN. Richmond et al. (1992a) reported that in order to avoid any confusion in clinical examination, the use of the Dental Health Component ruler was necessary for

malocclusion examination based on the Index of Orthodontic Treatment Need. Description of the DHC ruler is as shown in Appendix 3.

Table 2.12: Summary of studies based on normative orthodontic treatment need

Authors (year)	Population	Subjects		Registration Method	Need for Treatment (%)		
		N	Age (years)		No need	Border line	Definite
Burden and Holmes (1994)	Manchester	874	11 - 12	DHC			31
	Sheffield	955					32
Brikeland et al. (1996)	Norwegian	359	11	DHC	46.8	27	26.2
Stenvik et al. (1996)	Norwegian	50	18	NOTI	74	26	0
		73	35		52	40	8
Otuyemi et al. (1997)	Nigerian	704	14 mean	DHC	61.5	25.9	12.6
Ng'ang'a et al. (1997)	Kenyan	919	13 - 15	NOTI			29
Ugur et al. (1998)	Turkish	572	6 - 10	TPI	62	25	13
Mandall et al. (2000)	Manchester	434	14 - 15	DHC	48	34	18
Hamdan (2001)	Jordanian	320	14 - 17	DHC	50.3	22.2	27.5
Abdullah and Rock (2001)	Malaysian	5112	12 -13	DHC	20.3	31.8	46.9
Esa et al. (2001)	Malaysian	1519	12 - 13	DAI	62.6	19.6	27.8
Üçüncü and Ertugay (2001)	Turkish	250	11 - 14	DHC	37.2	24	38.8
Abu Alhaija et al. (2004)	Jordanian	1002	12 - 14	DHC	26	40	34
Tausche et al. (2004)	German	1975	6 - 8	DHC	48.3	25.5	26.2
Kerosuo et al. (2004)	Kuwaiti	139	14 - 18	DHC	57	38	38
Souames et al. (2006)	French	511	9 - 12	DHC	50.1	28.6	21.3
Bernabé and Flores-Mir (2006a)	Peruvian	281	18	DHC	35.2	34.9	29.9
Hedayati et al. (2007)	Iranian	2000	11 - 14	DHC	55.7	25.8	18.4
Ajayi (2008)	Nigerian	261	12 - 14	DHC	63.2	17.6	19.2

Continued Table 2.12

Shivakumar et al. (2009)	Indian	1000	12 - 15	DAI	80.1	15.7	4.2
Sharma (2009)	Nepalese	700	7 - 48	DHC	9.9	28.1	62
Safavi et al. (2009)	Iranian	5200	14 - 16	DHC	57	23	20
Chu et al. (2009)	Chinese	240	18 - 27	DHC	20	47	33
Manzanera et al. (2009)	Spanish	363	12	DHC	46.5	31.7	21.8
		292	15 - 16		63.4	19.5	17.1
Danaei and Salehi (2010)	Iranian	900	12 - 15	DAI	70.0	18.0	12.0
Dias and Gleiser (2010)	Brazilian	407	9 - 12	DHC	42.3	23.5	34.2
Poonacha et al. (2010)	Indian	100	12 - 14	DAI	3.0	15.0	82.0
Perillo et al. (2010)	Italian	703	12	DHC	35.8	36.7	27.3

2.4.3.18.2 Aesthetic Component (AC) of IOTN

Dental appearance is an important aspect of human motivation for orthodontic treatment (Burden and Pine, 1995). However, some children are not aware that they have occlusion problems, while others consider orthodontic treatment as being unaffordable. Orthodontic treatment needs perceived were varied with different social and cultural environment (Wheeler et al., 1994).

The Standardised Continuum of Aesthetic Need (SCAN) by Evans and Shaw (1987) was utilised in the Index of Orthodontic Treatment Need as component of measuring aesthetic. The AC scale was constructed using dental photographs of 1000 subjects, age 12-years old. A panel of six lay judges related these photographs on a visual analogue scale, and at equal intervals along the judged range.

Representative photographs were chosen giving a ten point scale as follows:

Grades 1, 2, 3 and 4 - No/ Slight need for treatment

Grades 5, 6 and 7 - Moderate / Borderline need for treatment

Grades 8, 9 and 10 - Great / need for treatment.

Each rating was gained by measuring the expanse in millimetres between the very unattractive ends of the scale corresponds to 10 possible degrees of dental attractiveness (Brook and Shaw, 1989). Number 1 is the most, and number 10 the least attractive arrangement of teeth (Appendix 4).

When assessing Aesthetic Component of IOTN, it is important to note that the anterior teeth should be graded in their dental attractiveness as seen. Stained restorations, chipped teeth and poor gingival conditions should be ignored in this assessment. Future appearance of the dentition could not however, be made by this assessment method (Richmond et al., 1992a). In many populations, the subjective need for orthodontic treatment had been determined by using the Aesthetic Component of IOTN, as have been done in studies listed in Tables 2.13 & 2.14.

Table 2.13: Summary of studies of orthodontic treatment need according to subject's perception

Authors (year)	Population	Subjects		Registration Method	Need Treatment (%)		
		N	Age (years)		No need	Border line	Definite
Birkeland et al. (1996)	Norwegian	359	11	AC	77.5	13.5	9.0
Chi et al. (2000)	New-zealanders	152	13	AC	92.1	7.2	0.7
Mandall et al. (2001)	Manchester	439	11 - 12	AC	83	14	3.0
Üçüncü and Ertugay (2001)	Turkish	250	11 - 14	AC	90.4	4.8	4.8
Abdullah and Rock (2002)	Malaysian	5112	12 -13	AC	82.7	7	5.8
Grzywacz (2003)	Poland	84	12	AC	94	6	0

Continued Table 2.13

Bernabé and Flores- Mir (2006a)	Peruvian	281	18	AC	87.5	10.6	1.8
Hedayati et al. (2007)	Iranian	2000	11 - 14	AC	91.9	3.9	4.1
Kolawole et al. (2008)	Nigerian	242	11 - 14	AC	92	4.6	3.4
Dias and Gleiser (2010)	Brazilian	407	9 - 12	AC	84.3	10.6	5.1

Table 2.14: Summary of studies of treatment need according to examiner assessment

Authors (year)	Population	Subjects		Registration Method	Need Treatment (%)		
		N	Age (years)		No need	Border line	Definite
Burden and Holmes (1994)	Manchester	874	11 - 12	AC	Not available		12
	Sheffield	955			Not available		8.5
Brikeland et al. (1996)	Norwegian	359	11	AC	70.5	21.7	7.7
Otuyemi et al. (1997)	Nigerian	704	mean 14	AC	66.4	26.6	7
Mandall et al. (2000)	Manchester	434	14 - 15	AC	72	19	9
Chi et al. (2000)	New-zealanders	152	13	AC	86.2	11.2	2.6
Abdullah and Rock (2002)	Malaysian	5112	12 - 13	AC	41.7	35.1	22.8
Mandall et al. (2001)	Manchester	439	11 - 12	AC	46	35	19
Grzywacz (2003)	Poland	84	12	AC	85.7	13.1	2.4
Mugonzibwa et al. (2004)	Tanzanian	386	9 - 18	AC	60	29	11
Hedayati et al. (2007)	Iranian	2000	11 - 14	AC	91.3	2.4	6.2
Kolawole et al. (2008)	Nigerian	242	11 - 14	AC	62.4	30.2	7.4
Ajayi (2008)	Nigerian	261	12 - 14	AC	87.7	7.7	4.6
Manzanera et al. (2009)	Spanish	363	12	AC	85.4	10.2	4.4
		292	15 - 16		93.5	4.1	2.4
Dias and Gleiser (2010)	Brazilian	407	9 - 12	AC	62.2	26.5	11.3

2.4.3.18.3 Validity and Reliability of IOTN

Index of Orthodontic Treatment Need was initially validated by Brook and Shaw (1989) and Shaw et al. (1991). Later, validity and reliability of IOTN was extensively verified by several investigators. Richmond et al. (1995) used assessment of 256 dental casts and values from the 10-photographs by a panel of 74 dentists (22 consultant, 22 specialist, 15 dental practitioners, 11 community dentists, 2 members of the Dental Practice Board, and 2 junior hospital staff). A Spearman's correlation coefficient of 0.86 was found for Aesthetic Component, while the Dental Health Component showed a coefficient of 0.64. Both coefficients indicated good correlation with the subjective opinions of the panel.

Younis et al. (1997) studied the reliability and validity of an Index of Orthodontic Treatment Need from the opinion of a panel of 18 orthodontists. A set of 160 study casts representing all types of malocclusion was used. The diagnostic accuracy or validity of the orthodontic ratings was calculated. The results indicated that IOTN provided valuable information for determining orthodontic treatment need.

A longitudinal study of reliability of IOTN was done by Tarvit and Freer (1998). They reported on the assessment of dental occlusion for orthodontic purposes over time. Photographs and dental casts of 45 subjects at 12 years old were compared with follow-up records at 16 years of age. No orthodontic treatment was given during the 4 years. Four orthodontists with experience recorded the Aesthetic Component of IOTN while one of the authors calculated the Dental Health Component of IOTN scores for both series of dental casts. The results showed non-significant reduction in Aesthetic Component of IOTN across the whole sample was observed. However, the Dental Health Component of IOTN was proven to be more stable over the study period.

The validity of the Index of Orthodontic Treatment Need grades assessment over time was also confirmed by Cooper et al. (2000) in their study involving 314 subjects aged 11 and 15 years old, and 142 subjects aged 19 years. The sample included were those who had not received orthodontic treatment or extractions. The changes in the AC and the DHC of IOTN were measured. It was found that DHC was reliable over time however, the AC tended to show an improvement over time. This study provided some reassurance to clinicians that an IOTN grading at age 11 years was unlikely to change by the time the subject reached 19 years old.

The reliability and validity of IOTN formed the focus of a study by Beglin et al. (2001) in which the opinion of a panel of 15 experienced orthodontists were taken. They used 170 casts representing the full spectrum of malocclusion. The mean rating of the panel on treatment need was used as the gold standard for evaluating the validity of the index. The IOTN was observed to be a valid measure of treatment need as perceived by orthodontists.

In a more recent study, Ovsenik and Primožič (2007) studied 100 pre-treatment study casts of adolescent patients in the permanent dentition period. A panel of 10 orthodontists separately rated the same casts for malocclusion severity degree. The mean scores of the panel were analysed. In addition the ten randomly selected casts were re-evaluated for reliability. In conclusion, they found that the IOTN was a valid and reliable method for malocclusion assessment.

2.4.3.19 Need for Orthodontic Treatment Index, NOTI (1992)

NOTI was used by the Norwegian Health Insurance Administration for reimbursement of treatment costs. According to Grytten et al. (2010) children under 18 years of age in Norway could be refunded for all or part of the cost of orthodontic treatment depending on the severity of malocclusion.

NOTI, developed by Espeland et al. (1992), consisted of a single component that encompassed a number of variables, corresponding to various abnormalities of occlusion. During clinical examination, dental models and radiographs of the patient was assigned to one of 4 categories of needs for treatment. The four categories of needs were made up of various malocclusion severities. The highest scoring traits recorded were used to determine the category of the treatment need designated by letters (A, B, C, and D):

- Category A: cleft lip and palate inherited or acquired craniofacial anomalies, severe anomalies requiring a combination of orthodontic and orthognathic surgery, and anomalies of comparable; this category represents 'Very great need for treatment'.

- Category B: overjet more 9 mm, unilateral buccal or lingual crossbite, anterior openbite with occlusal contact on molars only, impacted incisors and canines, anterior crossbite on all incisors, anterior teeth missing, increased overbite with labial or palatal impingement of the soft tissue, bilateral buccal crossbite, agenesis of two or more teeth in the same quadrant (excepted third molars) and anomalies of comparable severity, this category represents 'Great need for treatment'.

- Category C: overjet 6-9 mm, openbite on three or more pairs of opposing teeth, inversion of anterior teeth, increased overbite without contact on anterior teeth

or with contact on the gingival ¼ of palatal surface of maxillary anterior teeth, agenesis of single teeth in the lateral segments, central diastema of 3 mm or more or pronounced general spacing of anterior segments, pronounced crowding of anterior teeth, occlusal disorder combined with strong subjective dysfunction symptoms and anomalies of comparable severity, this category represents 'Obvious need for treatment'.

- Category D: overjet less than 6 mm, bilateral crossbite, anterior and posterior openbites on fewer than three pairs of opposing teeth, increased overbite with occlusal contact incisal to the gingival ¼ of the palatal surface of the maxillary anterior teeth, local cross and scissor bites without asymmetry or forced bite, moderate crowding in anterior and lateral segments, central diastema less than 3 mm, and moderate spacing in anterior and lateral segments, this category represents 'Little or No need for treatment'.

This index ensured refund for orthodontic treatment in category A or B. Although NOTI had been used in various populations (Ng'ang'a et al., 1997; Stenvik et al., 1996), it was found not practical to be used in large epidemiological studies sample due to the need to include radiographs, dental models and clinical examination. In addition, this index was more time consuming, required more materials and a higher cost to implement.

2.4.3.20 Index of Complexity Outcome and Need, ICON (2000)

Daniels and Richmond (2000) developed a single index that was capable of evaluating the need, complexity and outcome of orthodontic treatment. An international panel of 97 orthodontists from nine different countries (United Kingdom, Germany, Greece, Hungary, Italy, Netherlands, Norway, Spain and United States) gave subjective judgments on the need for treatment, treatment complexity, treatment improvement and

acceptability on a diverse sample of 240 dental casts for assessment of treatment need and 98 paired pre-treatment and post-treatment cases for assessment of treatment outcome. The ICON consisted of five highly predictive components namely:

1) Aesthetic Component of IOTN, scoring range 1-10 and weight 7.
2) Presence of a crossbite (anterior and posterior), scoring range 0-5 and weight 5.
3) Upper arch crowding/spacing (impacted teeth immediately score 5), scoring range 0-1 and weight 5.
4) Buccal segment antero-posterior relationships (Angle Classification in both sides are scored then added together), scoring range 0-4 and weight 4.
5) Anterior vertical relationship (degree of incisor openbite/overbite), scoring range 0-2 and weight 3.

The sum of the scores and their weighting gave ICON a score of the case (Table 2.15). The pre-treatment score reflected the need for treatment, and also complexity of the treatment required, whereas the post-treatment score gave the acceptability.

Table 2.15: Need, acceptability and complexity score range of ICON

Interpretation		Period of Treatment	Score Range
Need of treatment		Pre-treatment	> 43
Acceptability		Post-treatment	< 31
Complexity	Easy	Pre-treatment	< 29
	Mild		29 to 50
	Moderate		51 to 63
	Difficult		64 to 77
	Very difficult		> 77

The ICON was scored again to measure any improvement observed (pre-treatment score minus 4 × post-treatment score) to give the degree of treatment improvement (Table 2.16).

Table 2.16: Improvement grades of treatment according to ICON

Improvement Degree of Treatment	Score Range
Greatly improved	> -1
Substantially improved	-25 to -1
Moderately improved	-53 to -26
Minimally improved	-85 to -54
Not or worse improved	< -85

The ICON method incorporates features of the Index of Orthodontic Treatment Need, IOTN and the Peer Assessment Rating, PAR (Mitchell, 2001). The practical application of the index was kept as simple as possible, and studies had shown that the index was reliable and easy to apply (Koochek et al., 2001; Savastano et al., 2003). ICON was also found to be an accurate and reliable method when using computer-based models **(**Veenema et al., 2009). This new index was used by many investigators (Liepa et al., 2003; Ngom et al., 2007 and Louwerse et al., 2006).

2.4.3.21 Treatment Difficulty Index (2006)

Pitt et al. (2006) developed the Treatment Difficulty Index (TDI) that could be used to measure the difficulty that would be expected during the alignment of an unerupted maxillary canine. The index was developed by having a set of records and information of cases assessed by 14 consultant orthodontists based on perceived difficulty of aligning the impacted canine. A score based on a scale from 1 to 5 (1 = easy, 5 = extremely difficult) was allocated. In addition, the panel select from a list of 10 below, up to four factors relating to the position of the unerupted canine which contributed to a difficulty grade. The latter was given a rank value from 4 (most important) to 1 (least important):

(1) Rotation.
(2) Angulations to midline.
(3) Age of patient.
(4) Coincidence of arch midline.
(5) Alignment and spacing of upper labial segment.
(6) Vertical height.
(7) Bucco-palatal position.
(8) Condition of primary canine.
(9) Missing teeth.
(10) Horizontal position.

To achieve the purpose of obtaining a difficulty score total for each case, the relationship between the grade and contributory factors for each factor were analysed using regression. Findings indicated that horizontal position, age of patient, vertical height and bucco-palatal position, in descending order of importance, were the factors that determined the difficulty of canine alignment.

This index however only assessed specific factors of an impacted canine and provided a useful treatment planning aid for the management of impacted maxillary canines. It did not however give overall malocclusion traits measurement.

2.5 Selection of Measurement Methods for This Study

In summary, the literature review had shown that measurements of malocclusion remained to be inconclusive. There was no evidence of any one assessment method to be the most accurate in measuring malocclusion or its severity and in measuring orthodontic treatment need. Regardless of what index was used, findings still shared substantial differences in the prevalence of malocclusion among different populations. These differences were not only in ethnicity, sample size and age groups differences, but also in the variety of methods used.

Different measurements procedures had been used to study malocclusion. The most significant method in epidemiological studies was direct intra-oral measurements. Oral examination is a widely used method in research and clinical assessment, especially when the resources and number of investigators are limited. In recent years oral examination has been accepted as reliable and an excellent method for malocclusion assessment (Ovsenik et al., 2004). In addition, oral examination of malocclusion among 14-year-old adolescents was found to be highly reliable **(**Ovsenik et al., 2007). Although the radiographs and study models are significant methods to gain information on occlusal trait, but may not be possible to conduct under many field conditions and survey with a large sample size. These agree with recommendation of the father of FDI method of recording occlusal traits (Baume et al., 1973).

In this study, both the method for recording occlusal traits and Index of Orthodontic Treatment Need (IOTN) were used. The former was used as a base method to determine the prevalence and severity of malocclusion, as it had been approved by FDI/WHO and assessed main occlusal traits that are responsible for functional and aesthetic discrepancy. In addition, of does not exclude subjects with previous extractions. IOTN on the other hand was used in our attempt to develop a data base whereby findings can

be compared with other population groups. The Index of Orthodontic Treatment Need was chosen in this study as literature review had shown that could serve as a neutral instrument to determine treatment needs and to distribute financial resources for orthodontic patients. The IOTN had also been found to be widely used in assessing orthodontic treatment need in the Middle East (Hamdan, 2001; Abu Alhaija et al., 2004; Safavi et al., 2009).

2.6 Purpose of the Study

2.6.1 Aim

The aim of this study was to describe the occlusal traits, prevalence of malocclusion and estimation of orthodontic treatment needs in 14-year-old Yemeni adolescents.

2.6.2 Specific Objectives

1. To assess the occurrence of occlusal traits and prevalence of malocclusion among Yemeni adolescents based on FDI/WHO conventional method in terms of:
   i. Dental discrepancies (missing permanent teeth, supernumerary teeth, incisors malformation and retained deciduous teeth).
   ii. Space discrepancies (crowding, spacing and diastema).
   iii. Occlusal discrepancies
      - Antero-posterior relationship (molar relationship, maxillary and reverse overjet and anterior crossbite).
      - Vertical relationship (overbite, anterior and posterior openbites).
      - Transversal relationship (posterior crossbite and scissor bite)

2. To estimate the normative orthodontic treatment need of malocclusion using the dental health component of Index Orthodontic Treatment Need (IOTN)

3. To estimate the orthodontic treatment need for malocclusion as evaluated by the examiner and self-perceived by the subjects.

4. To compare the occlusal traits and orthodontic treatment need as measured in (1) – (3) by demographic variables that include geographical zones, location (urban and rural) and gender.

5. To compare the prevalence of malocclusion as measured by the FDI/WHO conventional method and the Index of Orthodontic Treatment Need.

6. To recommend a measurement tool, with modification if necessary, for assessing malocclusion and orthodontic treatment need in Yemeni population.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The background of the study area has been covered in chapter two. The population of Yemen is around 20 millions (Central Statistical Organisation Report, 2004). Of this, 50.3% are those aged 14 years old and below. The study involved both government and private schools in Yemen. The sample of the present study was selected from nine governorates in Yemen (Figure 3.1). The governorates were then divided into five zones covering different climatic characteristics namely; Mountains, Plateaus, Coast, Desert and Islands. Specific study sites were:

1) Sana'a and Capital City of Sana'a in the north of Yemen (Mountainous areas).
2) Aden and Taiz in the south of Yemen (Coastal areas).
3) Thamar and Ibb in the middle of Yemen (Plateau areas).
4) Al-Hudaydah and Kamaran island in the west of Yemen (coastal and island areas).
5) Hadramawt and Shabwah in the east (Desert areas).

The population of the nine selected governorates made up two thirds (64.8%) of the total population of Yemen. The numbers of 14-year-old students in the nine governorates made up 70.8% of the total 14-year-old Yemeni population (Table 3.1).

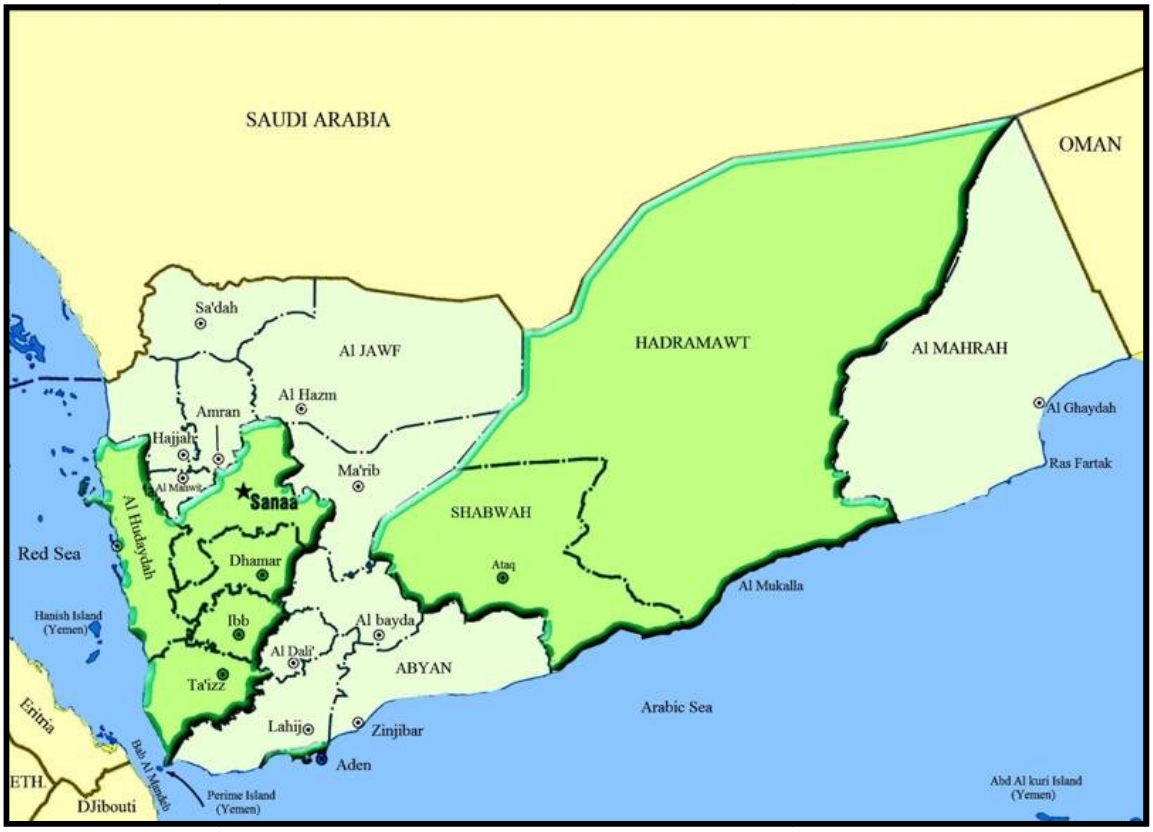


Figure 3.1: Distribution of nine governorates (green colour) in map of Yemen

Table 3.1: Number of 14 year-old intermediate school students of nine included governorates and total population of Yemen (Ministry of Education Report, 2004)

Location	14 – year old students			Total population
	Males	Females	Total	
Capital City of Sana'a	17446	14613	32059	1,747,627
Sana'a	11027	2326	13353	918,379
Aden	4973	4117	9090	590,413
Taiz	30003	19061	49064	2,402,569
Thamar	13536	3015	16551	1,339,229
Ibb	22620	8350	30970	2,137,546
Al-Hudaydah	10503	6184	16687	2,161,379
Hadramawt	7691	3299	10990	1,029,462
Shabwah	3899	318	4217	466,889
Subtotal of nine governorates	121698	61283	182981	12,793,493
Total Yemen population	179992	78322	258314	19,721,643

3.2 Study Design

This is a cross-sectional epidemiological study conducted on a representative sample of 14-year-old intermediate school students selected across five zones of Yemen, equally distributed by gender and location (urban and rural).

3.3 Sampling

Sampling included sample size calculation, determination of age sample, selection of schools and subject.

3.3.1 Sample Size Calculation

Determination of an appropriate sample size is an essential part of research. Inadequate sample size will influence the quality and accuracy of research analysis. Awareness in the calculation of a minimum sample size required and the application of appropriate sampling methods used are extremely important in achieving scientifically and statistically sound results (Lenth, 2001; Hoenig and Heisey, 2001).

If the sample size is too small, even a well conducted study may fail to answer its research question, or may fail to detect important effects or associations. Similarly, if the sample size is too large, the study will be more difficult and costly, and may even lead to a loss in accuracy. Thus, optimum sample size is an essential component of any research (Campbell et al., 2007)

In order to get a true representation of the target population, the sample size determination calculated used the results of orthodontic treatment need study of school children in the Middle region (Riyadh) of Saudi Arabia as measured by IOTN (Al-Sarheed et al., 2003) as its reference point. The prevalence of the Saudi study was taken as estimation for the initial rate (P) in calculations for the sample (N). The decision was made since no previous studies had ever been carried out in Yemen, and Saudi Arabia is

bordering Yemen in the north. Their study indicated that the need for orthodontic treatment among 11–16 year-olds Saudi children was 30%.

The estimated minimum sample size was calculated according to the following formula (Abdul Kadir, 1989).

$$N = \frac{U^2 \; P \; Q}{E^2}$$

$$N = \frac{(1.96)^2 \; (30) \; (70)}{5^2} = 323$$

Where:

N = required sample size to be examined.

U = the factor according to probability more to factor "e", this factor is equal to 1.96 equivalence with level of 95% probability.

P = estimated initial rate.

Q = (P-1), estimated initial rate for citizen and not infected.

E = maximum error allowed in prevalence estimation 5%.

According to the calculation, the minimum sample size for one zone was 323 subjects. A total minimum sample size of 1615 was then required for five zones. The size of the sample was increased to represent approximately 1% of the target population (Hamdan, 2001). The final sample size determined was 480 subjects for each of the five zones (north, south, middle, east and west) (Table 3.2).

Table 3.2: Distribution of sample by zones, location (urban and rural) and gender

Demographic variables		Number of Sample	Percentage
Zones	North	480	20.0
	South	480	20.0
	Middle	480	20.0
	East	480	20.0
	West	480	20.0
	Total	2400	100
Location	Urban	1200	50.0
	Rural	1200	50.0
	Total	2400	100
Gender	Males	1200	50.0
	Females	1200	50.0
	Total	2400	100

3.3.2 Determination of Age of Sample

This study was performed on the sample age that should be having a full set of permanent teeth except third molars. This dentition stage has been considered the most reliable assessment of malocclusion in the population (Gray and Demirjian, 1977). Age of subjects included in the study ranged from 14 years 0 months to 14 years 11 months. This age group was selected because the full complement of the permanent teeth could expect to be in the mouth and without the perio-prosthodontic problems (Baume et al., 1973).

In case the age of the sample is younger than 14 years old, the measurements of certain occlusal traits such as impacted and partially erupted teeth were not recorded in actual figure (Kerosuo et al., 1988). Also, real changes in malocclusion occur with time and during childhood stage or mixed dentition development for example, overjet may improve enough to reduce the recommendation for treatment (Tarvit and Freer, 1998). It

was also noted that dental epidemiological investigators had argued that values recorded in the transitional dentition need not necessarily predict the future severity of malocclusion in the permanent dentition (Ghafari et al., 1989; El-Mangoury and Mostafa, 1990).

The majority of patients with malocclusion in Yemen who came seeking orthodontic treatment were during the period of adolescence, with completed permanent teeth in the mouth. For these reasons it was decided to examine the 14 years old because adolescents at this age were considered to be sufficiently mature and self-confident to be able to make a balanced judgement for the relative dental aesthetic evaluation. This opinion was proven in a study conducted by Stenvik et al.(1997). They found that children in the early ages were significantly less critical in their aesthetic judgement.

3.3.3 Selection of Schools

A multi-stage stratified random sampling technique was used in selecting the schools. All public and private intermediate schools in each governorate were listed and allocated numbers. Two lists were prepared, one for male and the other female schools. Urban schools were defined as schools in developed cities or towns. Rural schools were defined as schools outside the periphery of the capital city or large townships.

Based on the above criterion, the capital city of Sana'a was specified as the urban setting for the north zone while the villages surrounding the Sana'a governorate were considered as rural. In the south zone, Aden and Taiz Cities were listed as urban while the periphery of Taiz was considered as rural. All other governorates have defined urban and rural areas. An inclusion criteria used was that a school must have an enrolment of at least forty 14 year-old students. In each zone, twelve schools from the schools listed were randomly selected, equally selected in terms of gender and location (urban and rural) (Figure 3.2).

3.3.4 Selection of Sample

The total number of sample subjects required for this study was 2,400 comprising of 50% males and the remaining females. The sample was taken from sixty schools, equally distributed in terms of urban and rural (Figure 3.2). In schools that have an enrolment of more than 40 students, the subjects were randomly selected by balloting. However, some rural schools have only one class of 40 students. In such a case, a convenient sampling technique was used. Eight rural schools did not have the targeted number. In such a situation, the number was compensated at the next nearest school in the area. This procedure was deemed to be most appropriate because schools in rural areas (especially in the desert and mountain-plateau areas) were sporadically located, some in isolation from other areas and far apart. In addition, the geographical terrain was not conducive and cost-effective for the examiners to travel far between. Final sample was based on inclusion criteria that all subjects were 14 years old, of Yemeni origin, with permanent teeth. Exclusion criteria were not having any type of orthodontic treatment, maxillofacial surgery and those with mixed dentition.

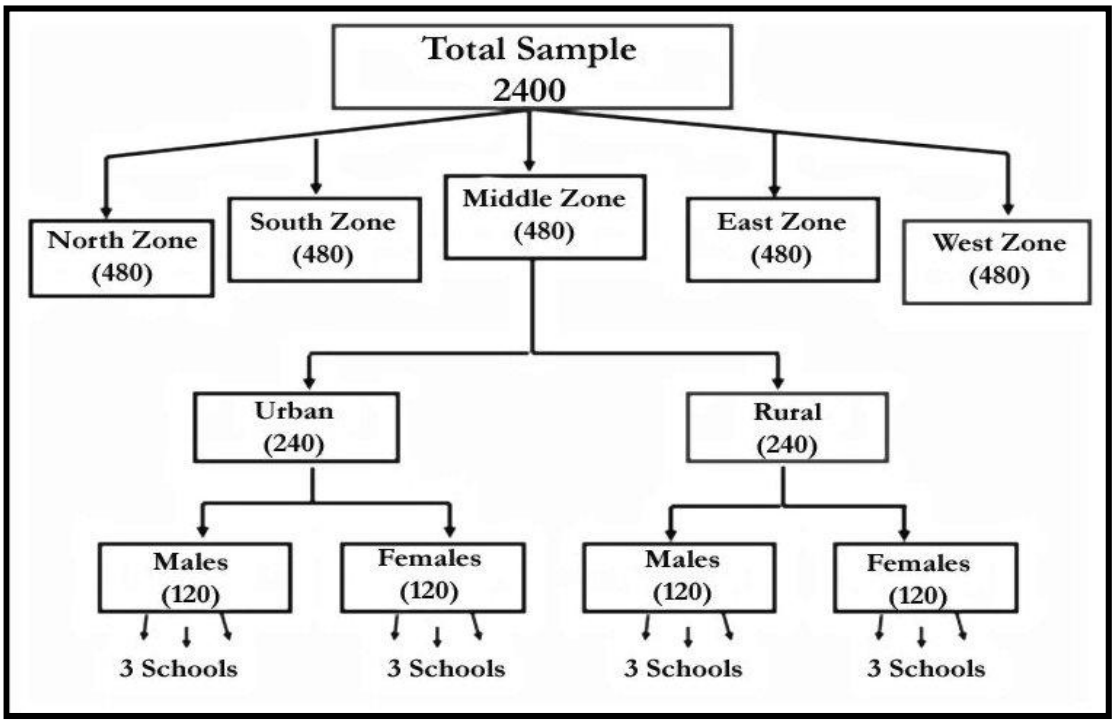


Figure 3.2: Flow chart of the sample selection (giving middle zone as an example)

3.4 Administration of Study Conduct

The administration of study conduct included permissions, equipment and infection control of this survey.

3.4.1 Ethical Approval and Permissions

Ethical Approval for the study was obtained from the Scientific Research Committee at University of Malaya (Appendix 5). A letter from the supervisor certified by the Yemeni embassy in Kuala Lumpur was sent to Thamar University in Yemen to seek support in seeking permission from local authorities as well as in organising the data collection segment for the study in Yemen (Appendix 6). Subsequently, the Vice-Rector, Postgraduate Studies & Scientific Research, Thamar University wrote a letter to the Director of Education, Yemen to obtain permission to allow the investigator to continue with other administrative protocol and communication to all nine education governorate directors, Ministry of Education (Appendices 7 & 8). Copies of protocol and permission letters were given to participating schools' headmasters. This was done so as to ensure full cooperation for the study data collection to run smoothly (Appendices 9 & 10). All subjects participating in the study received detailed information about the research and signed a consent form to participate in the oral examination and photograph taking (Appendices 11 & 12).

3.4.2 Instruments and Equipment

Prior to the study conduct, administrative preparation was made to ensure all equipments and instruments to be used in the study had been purchased and prepared for use. The itineraries of the instruments used were as listed and shown in Figure 3.3 and Appendix 3.

Figure 3.3: Instruments and equipment used in the study

3.4.3 Infection Control

Infection control procedures were strictly adhered to. Only disposable dental mirror and disposable Dental Health Component (DHC) rulers were used. In addition, the examiner wore gloves and masks throughout the examination. After each examination, mirrors, gloves and DHC rulers were disposed into a waste bag. Gloves were disinfected using disinfectant solution, but if contact had been made with oral mucosa or saliva, the gloves were changed.

3.5 Measurement Tool and Criteria

The measurement criteria were divided into three main groups:

I. Registration method for recording occlusal traits and prevalence of malocclusion developed by FDI (Baume et al., 1973) and modified version of objective method that was approved by WHO (Bezroukov et al., 1979) was used as the standard for occlusal traits assessment as follows.

- Dental discrepancies
- Space discrepancies
- Antero-posterior occlusal relationship discrepancies
- Vertical occlusal relationship discrepancies
- Transversal occlusal relationship discrepancies

II. Additional occlusal traits observed in clinical examination.

III. Measurement of orthodontic treatment need of malocclusion, the Index of Orthodontic Treatment Need (IOTN) developed by Brook and Shaw (1989) and modified by Richmond and co-workers (1995) was used.

The registration form of clinical examination for occlusal status and orthodontic treatment need used were as presented in Appendix 13.

3.5.1 Occlusal Traits Based on FDI/WHO Method

3.5.1.1 Measurement of Dental Discrepancies

Measurements of dentition were recorded to assess the status of individual teeth. Each tooth was assessed for the conditions listed.

3.5.1.1.1 Missing Permanent Teeth

Taking into account the subject's dental development, by the age of 14 years the subjects should have a full set of permanent teeth except for the third molars. However, any permanent tooth that was not visible in the mouth after considering dental development age was measured as missing (impacted, congenitally absent or extracted). Relevant questions to the subjects may often be helpful in making differential diagnosis within missing teeth category. Differences between various reasons for the missing tooth were also made based on the FDI method criteria (Baume et al., 1973; and Bezroukov et al., 1979) as follows.

- A tooth was recorded as impacted if there was no history of prior extractions, and the contour of the underlying ridge bulging indicated the presence of a tooth (Figure 3.4).

- If the subject had no history of prior extractions and the contour of the underlying ridge was normal and no bulging or there was reduction in alveolar bone in the site, it was assumed that the tooth was congenitally absent (Figure 3.5).

- A tooth was considered missing due to extraction or trauma when there was reduction in alveolar bone in the site with history of prior extractions (Figure 3.6).

Figure 3.4: Impacted lower canine clinically observed as bulging ridge

Figure 3.5: Clinically absent maxillary lateral incisors

Figure 3.6: Missing central incisor due to extraction which was confirmed from history and observed reduction in alveolar bone

3.5.1.1.2 Supernumerary Teeth

Supernumerary tooth is when an additional tooth to the normal series of permanent teeth is counted regardless of its shape or size (Figure 3.7). The numbers of supernumerary teeth were recorded in any region of the dental arch. A supernumerary tooth was not recorded as malformation.

Figures 3.7: Supernumerary tooth with displacement of teeth

3.5.1.1.3 Incisors Malformation

The number of malformed teeth is recorded when an erupted incisor of abnormal size or shape when the mesio-distal width is reduced or increased by 2 mm or more. The position and shape of these teeth may be specified in the space provided. Abnormal eruption due to transposition or retained deciduous teeth is not recorded.

3.5.1.1.4 Retained Deciduous Teeth

The presence of deciduous teeth were recorded, whether the successor permanent teeth had erupted or not.

3.5.1.2 Measurement of Space Discrepancies

The scoring involved measuring the amount of crowding or spacing which was recorded in both maxillary and mandibular arches separately. Crowding and spacing were categorised as follows: No crowding or spacing, less than 2 mm, and 2 mm or more. On the other hand, maxillary midline diastema of 2 mm and more also was measured. The DHC ruler was used to measure the amount of space discrepancies.

3.5.1.2.1 Crowding

Crowding was measured between anatomical contact points when the teeth deviate from the line of the arch (Figure 3.8). Crowding between deciduous and permanent teeth was not recorded.

Figure 3.8: Crowding of lower arch (distance between anatomical contact points)

3.5.1.2.2 Spacing

Spacing was measured between anatomical contact points when the teeth were located within the line of the arch. Diastema was also included in the measurement if the subject has a generalised spacing (Figure 3.9). However, spacing between deciduous and permanent teeth is not recorded.

Figures 3.9: Generalised spacing

3.5.1.2.3 Maxillary Midline Diastema

Maxillary midline diastema of 2 mm or more without other spacing was measured horizontally at all levels between the mesial surfaces of the central incisors. If either maxillary central incisor were missing, no assessment was made for diastema.

3.5.1.3 Measurement of Antero-posterior Occlusal Relationship

Assessments of antero-posterior occlusal relationship included normal and deviation in the positional relationship between maxilla and mandible dental arches in antero-posterior direction. In order to make these assessments, the subjects must achieve centric occlusion.

3.5.1.3.1 Molar Relationship

The antero-posterior relationship of the first permanent molars was recorded on each side. A mouth mirror was used to retract each cheek successively and the molar relationship was viewed directly or in the mirror at right angle to the buccal surfaces (Baume et al., 1973). According to modified Angle Classification, one of nine separate relationships was recorded on each side of the mouth for the antero-posterior occlusion of the maxillary and mandibular first molars. Extracted molar and badly broken caries of tooth were excluded.

Class I: The mesiobuccal cusp of maxillary first permanent molars lies in the mesiobuccal grooves of the mandibular first permanent molars (Figure 3.10).

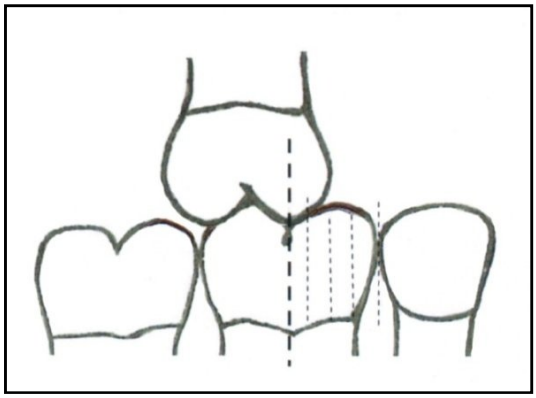


Figure 3.10: Class I molar relationship

Class II: The mesiobuccal cusp of the upper first permanent molars occludes mesial to the Class I position. The above also known as a post normal relationship has four units;

¼ Unit: The tip of mesiobuccal cusp of upper first molar occludes anywhere within mesial to mesiobuccal groove and distal to mesiobuccal cusp of lower first molar.

½ Unit: The tip of mesiobuccal cusp of upper first molar occludes on the tip of mesiobuccal cusp of lower first molar.

¾ Unit: The tip of mesiobuccal cusp of upper first molar occludes anywhere within mesial to mesiobuccal cusp of lower first molar and distal to embrasure between lower first molar and lower second premolar

Full Unit Class II: The tip of mesiobuccal cusp of upper first molar occludes in the embrasure between lower first molar and lower second premolar (Figure 3.11).

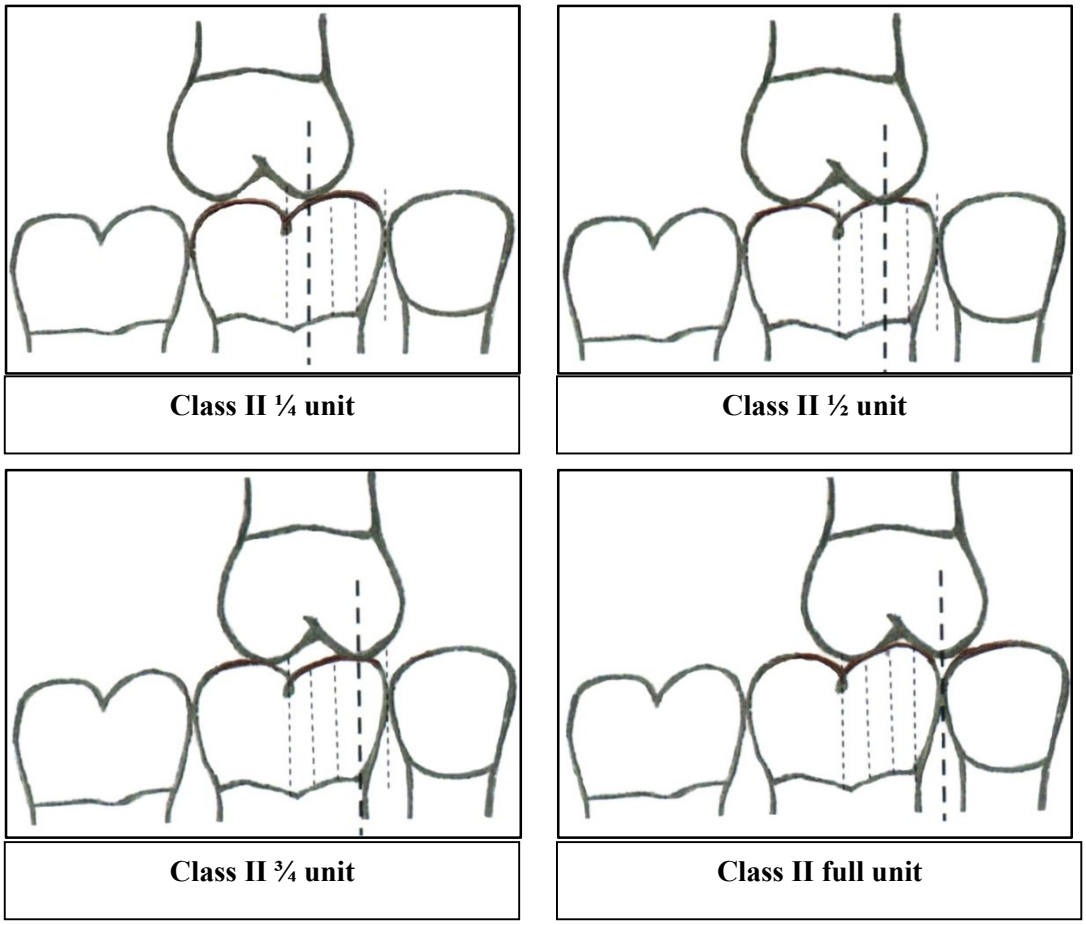


Figure 3.11: Class II molar relationship

Class III: The mesiobuccal cusp of the upper first permanent molars occludes distal to the Class I position. This is also known as a pre normal relationship, and has four units;

¼ Unit: the tip of mesiobuccal cusp of upper first molar occludes anywhere within distal to mesiobuccal groove and mesial to distobuccal cusp of lower first molar.

½ Unit: The tip of mesiobuccal cusp of upper first molar occludes on the distobuccal cusp of lower first molar.

¾ Unit: The tip of mesiobuccal cusp of upper first molar occludes anywhere within distal to distobuccal cusp of lower first molar and mesial to embrasure between lower first molar and lower second molar.

Full Unit Class III: The tip of the mesiobuccal cusp of upper first molar occludes in the embrasure between lower first molar and lower second molar (Figure 3.12).

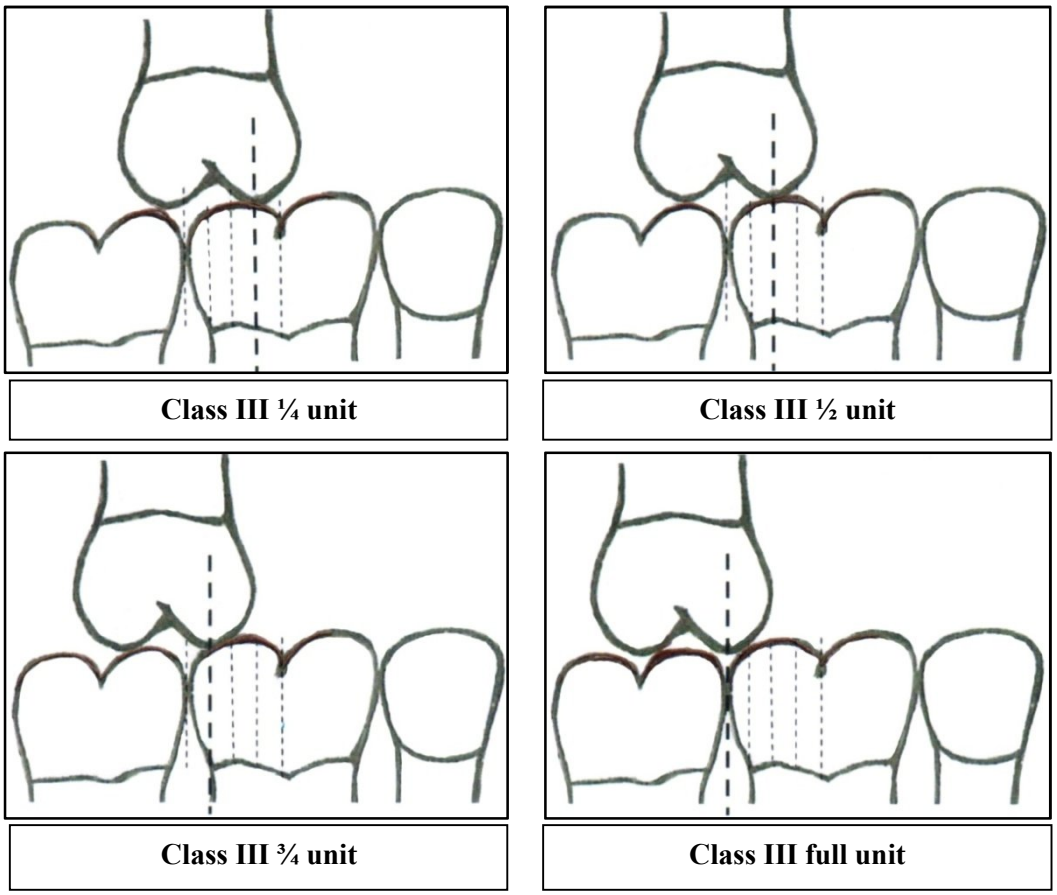


Figure 3.12: Class III molar relationship

3.5.1.3.2 Overjet

Horizontal distance (overjet) was measured from labial aspect of the incisal edge of the most prominent maxillary central incisor to the labial aspect of the opposing mandibular incisor parallel to the occlusal plane in centric occlusion. Overjet was measured using DHC ruler held parallel to the occlusal plane and classified according to the following: < 6 mm and ≥ 6 mm. If there was anterior crossbite or missing both upper central incisors, the maxillary overjet was not recordable.

Reverse overjet was recorded as present, only when all four maxillary incisors occluded lingual to the lower incisors. Edge to edge occlusion of maxillary and mandibular incisors was not regarded as reverse overjet.

3.5.1.3.3 Anterior Crossbite

Condition of anterior crossbite was scored only when three or fewer maxillary incisors occluded lingually to mandibular incisors (Figure 3.13). The score of anterior crossbite vary from 1 to 3 according to number of inverted maxillary incisors. Anterior crossbite was not scored when the reverse overjet was recorded.

Figures 3.13: Anterior crossbite of upper right lateral incisor

3.5.1.4 Measurement of Vertical Occlusal Relationship

These assessments include normal and deviation in the positional relationship between maxilla and mandible dental arches in vertical direction. In order to make these assessments the subjects must achieve centric occlusion.

3.5.1.4.1 Overbite

Overbite was considered as the maximum overlap of either maxillary central incisors in relationship to the mandibular incisors and was recorded in terms of crown heights of the mandibular incisors. Overbite was classified according to the following division:

i.	< 2/3 overlap	Less than middle third overlap
ii.	2/3 to < 3/3 overlap	Middle third to less than lower third overlap
iii.	3/3 overlap and over	Lower third overlap and over without or with gingival contact

3.5.1.4.2 Anterior Openbite

Anterior openbite was recorded if there was no vertical overlap of all four maxillary incisors (vertical gap) with any mandibular incisors when viewed in the occlusal plane (Figure 3.14).

Figures 3.14: Anterior openbite

3.5.1.4.3 Posterior Openbite

A measurement of the vertical relationship of the lateral segments was made by direct inspection of the lateral segments on both sides of the mouth. Posterior openbite was recorded as a distance of 2 mm and more between at least one pair of opposing teeth in the posterior segment (molars and premolars), (Bezroukov et al., 1979).

3.5.1.5 Measurement of Transversal Occlusion Relationship

These assessments included the abnormal features of occlusion in transverse relationship between maxilla and mandible dental arches. Normal transverse relationship of occlusion was recorded when the buccal cusps of the mandibular teeth articulated between the maximum heights of the buccal and lingual cusps of the opposing maxillary teeth.

3.5.1.5.1 Posterior Crossbite

Visual assessment from the canine to the second molar was done to record posterior crossbite in both sides of the mouth. It was recorded if the buccal cusp of maxillary tooth lies lingual to the maximum height of a buccal cusp of an opposing mandibular tooth (Figure 3.15). It was recorded as one of the three conditions; bilateral, unilateral right and unilateral left.

Figure 3.15: Posterior crossbite

3.5.1.5.2 Scissor bite

Scissor bite was recorded when a palatal cusp of maxillary tooth lay buccal to the maximum height of a buccal cusp of an opposing mandibular tooth in lateral segments (Figure 3.16). Visual assessment from the first premolar to the second molar was done on both sides of the mouth.

Figure 3.16: Scissor bite

3.5.2 Measurement of Additional Occlusal Traits Observed

Extra occlusal traits measurement included all malocclusion observed in the clinical examination which were not measured by FDI/WHO conventional method for recording occlusal traits.

3.5.2.1 Partially Erupted Teeth

Partially erupted teeth was visually assessed when a tooth did not fully erupt to reach the occlusal plane or level, tipped or impacted against its adjacent teeth (Brook and Shaw, 1989) (Figures 3.17).

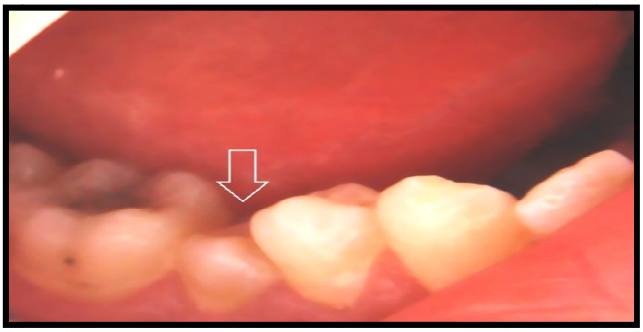


Figure 3.17: Partially erupted lower second premolar tipped and impacted against first premolar and first molar

3.5.2.2 Canine Relationship

The antero-posterior relationship of the permanent canine was measured on each side of the occlusion. According to modified Angle Classification, one of nine separate relationships was recorded on each side as follows:

Class I. The tip of the maxillary canine lies in the embrasure between the mandibular canine and the first premolar (Figure 3.18).

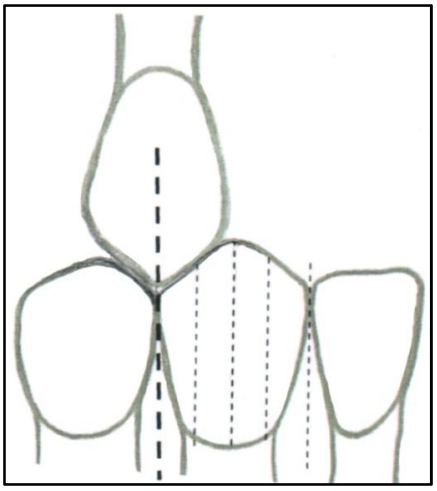


Figure 3.18: Class I canine relationship

Class II. The tip of the maxillary canine lies mesial to the embrasure between the mandibular canine and first premolar divided into four units (Figure 3.19).

¼ Unit: the tip of maxillary canine lies anywhere within mesial to the embrasure between the mandibular canine and first premolar, and distal to the tip of mandibular canine.

½ Unit: the tip of maxillary canine lies on the tip of mandibular canine.

¾ Unit: the tip of maxillary canine lies anywhere within mesial to the tip of mandibular canine and distal to the embrasure between the mandibular canine and lateral incisor.

Full Unit Class II: the tip of maxillary canine lies in the embrasure between the mandibular canine and lateral incisor, and mesially.

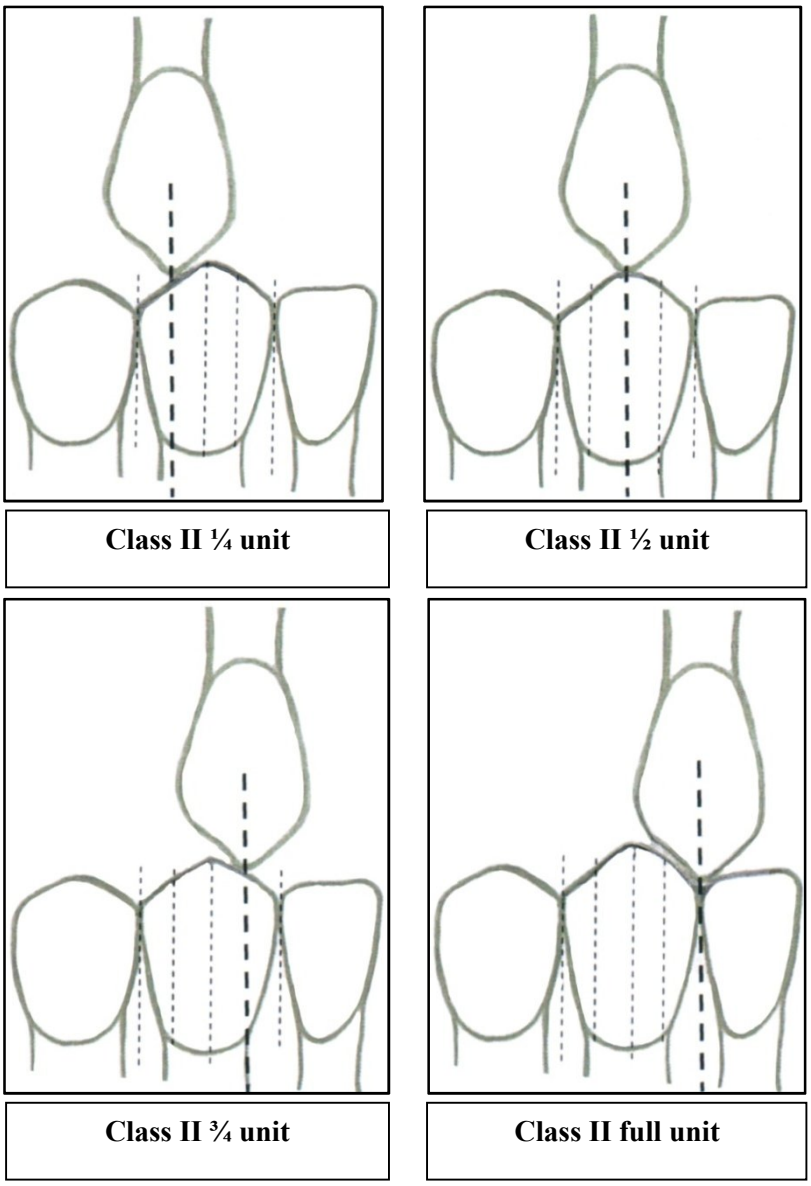


Figure 3.19: Class II canine relationship

Class III. The tip of the maxillary canine lies distal to the embrasure between the mandibular canine and first premolar divided into four units (Figure 3.20).

¼ Unit: the tip of maxillary canine lies anywhere within distal to the embrasure between the mandibular canine and first premolar, and mesial to the tip of mandibular first premolar.

½ Unit: the tip of maxillary canine lies on the tip of mandibular first premolar.

¾ Unit: the tip of maxillary canine lies anywhere within distal to the tip of mandibular first premolar and mesial to the embrasure between the mandibular first premolar and second premolar.

Full Unit Class III: the tip of maxillary canine lies in the embrasure between the mandibular first premolar and second premolar, and distally.

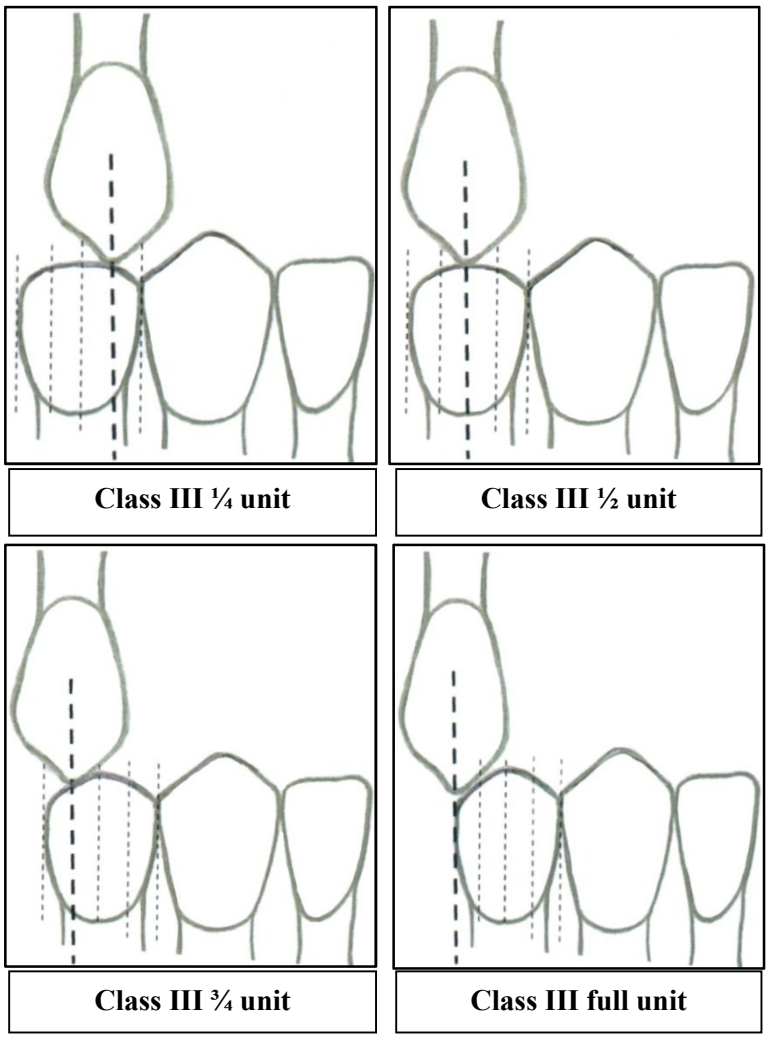


Figure 3.20: Class III canine relationship

3.5.2.3 Bimaxillary Protrusion

Bimaxillary protrusion was recorded when the subjects had Class I occlusal relationship with incompetent lips due to protruded of maxillary and mandibular teeth.

3.5.2.4 Incisor Classification

The measurement of incisor relationship was made by direct inspection of the anterior segment of occlusion with maximum interdigitation. The incisor relationship was measured according to the British Standard Classification of Malocclusion (BS 4492 1983) based on antero-posterior relationship. Incisor Classification was recorded as illustrated in Figure 3.21 and defined below.

Class I. The mandibular incisor edges occlude with or lie immediately below the cingulum plateau (middle part of the palatal surface) of the maxillary central incisor.

Class II. The mandibular incisor edges lie posterior to the cingulum plateau of the maxillary incisors. There are two divisions;

Division 1: There is increase in overjet and the maxillary central incisors are usually proclined, or

Division 2: The maxillary central incisors are retroclined, the overjet is usually minimal, but may be increased

Class III. The mandibular incisor edges lay anterior to the cingulum plateau of the maxillary incisor, the overjet is reduced or reversed.

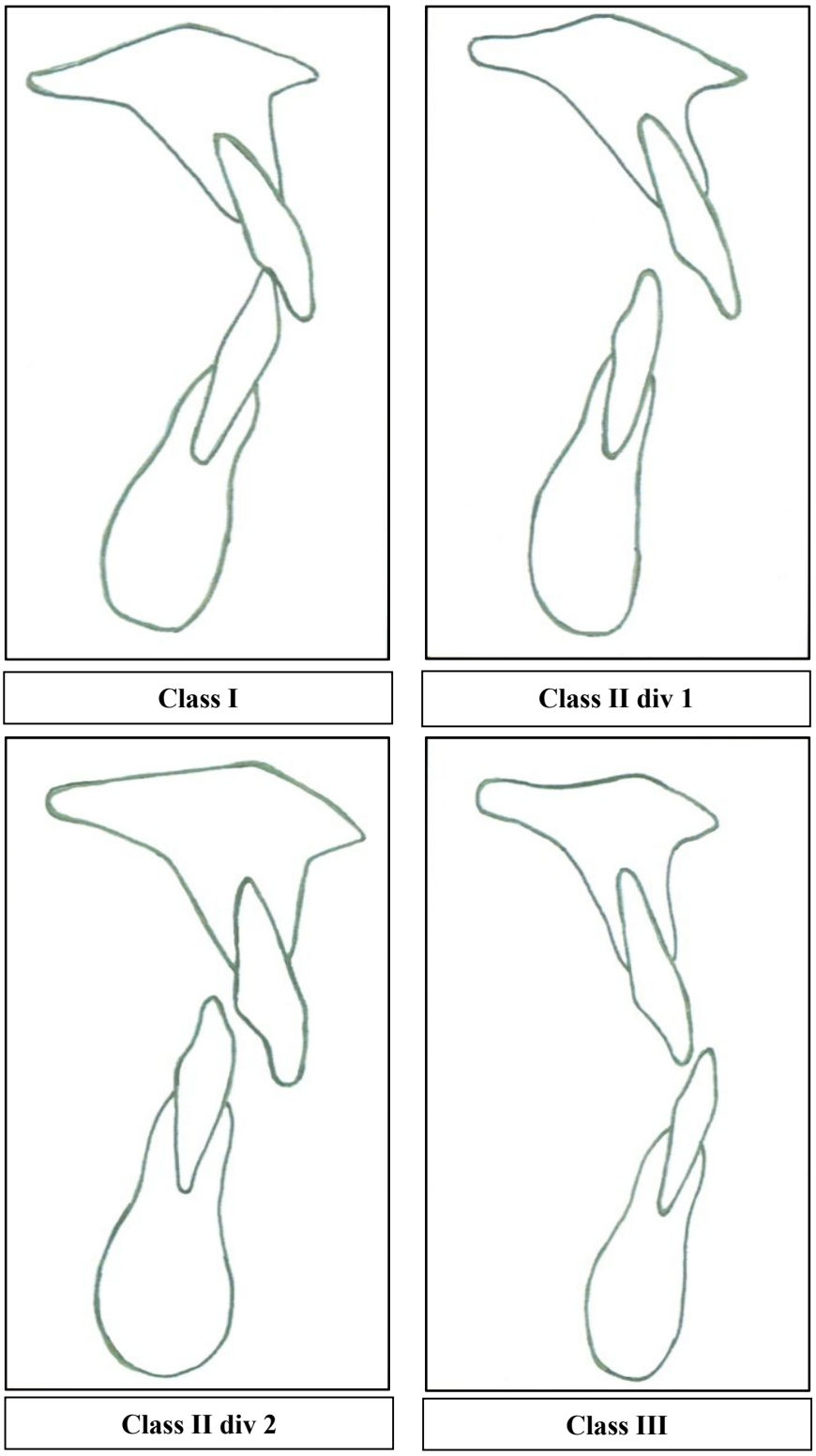


Figure 3.21: Incisor Classification relationship

3.5.3 Measurement of Orthodontic Treatment Need

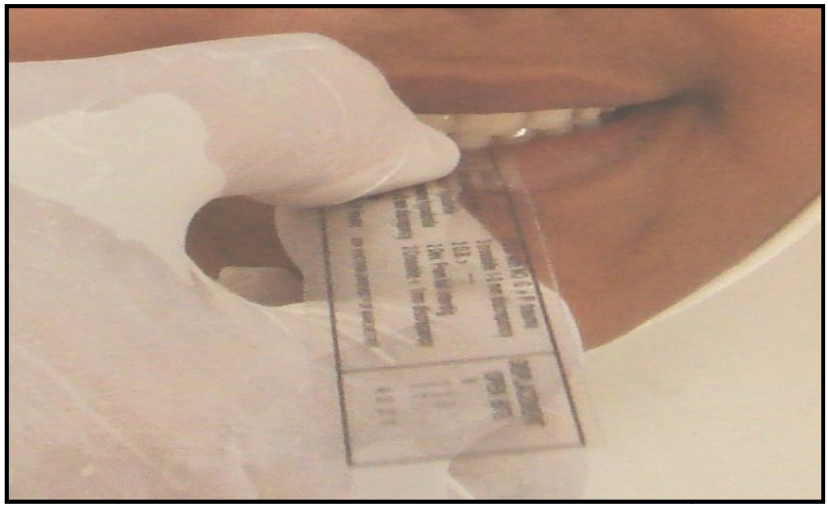
The Index of Orthodontic Treatment Need (IOTN) used in this study was made up of two components, namely; (1) Dental Health Component (DHC) to record the dental health and function indicated for treatment and (2) Aesthetic Component (AC) to record the aesthetic impairment caused by malocclusion.

3.5.3.1 Dental Health Component (DHC)

Dental health component was recorded by direct examination of the subjects and measured the various occlusal traits into five grades according to severity of malocclusion, as well as the need for orthodontic treatment. Whereas, Grades 1 and 2 represented 'No need' for treatment, Grade 3 representing 'Borderline need' for treatment and Grades 4 and 5 represented those in 'Definite need' of orthodontic treatment. The Dental Health Component of IOTN details were as described in Appendices 1 & 2.

Disposable DHC ruler was used to measure the malocclusion and followed the Hierarchical Scale (MOCDO) in order to identify the worst occlusal traits (Figure 3.22)

- Missing teeth (including congenital absence, ectopic and impacted teeth)
- Overjet (including reverse overjet)
- Crossbites
- Displacement
- Overbite (including openbite)



Figures 3.22: Disposable DHC ruler used in measurements of orthodontic treatment need

3.5.3.2 Aesthetic Component (AC)

Aesthetic Component measurement consisted of a scale of ten colour photographs showing different levels of dental attractiveness, Grade 1 represents the most attractive and, Grade 10 the least attractive dentitions. According to Richmond and co-workers (1995), Grades 1-4 represented 'No need' for treatment, Grades 5-7 'Borderline need' for treatment and Grades 8-10 'Definite need' for orthodontic treatment. Aesthetic Component (AC) of IOTN in this study was evaluated by examiner and subjects.

3.5.3.2.1 Aesthetic Component Evaluation by Examiner

Evaluation of Aesthetic Component of IOTN by examiner was made without attempting to predict future appearance of the dentition. Stained restoration, chipped teeth, poor gingival condition was ignored in assessment (Richmond et al., 1992a).

3.5.3.2.2 Aesthetic Component Evaluation by Subjects

After clinical examination, each subject was transferred to a quiet area for self assessment of Aesthetic Component of IOTN. The subject assessed his/her mouth with

a face mirror and then looked at the Aesthetic Component picture to choose the picture nearest to his/her dental appearance (Figures 3.23 & 3.24).

Figures 3.23: Aesthetic Component evaluation on a female subject in urban area

Figures 3.24: Aesthetic Component male evaluation on a male subject in rural area

3.6 Calibration

The calibration exercise was conducted to control for inter- and intra-examiner reliability. The gold standard was a lecturer in the Orthodontic Department at University of Malaya, who was trained in the United Kingdom and had been calibrated to use the IOTN and occlusal traits measurements. The examiner is an orthodontist with seven years clinical experience.

3.6.1 Laboratory Calibration

Two weeks prior to the calibration exercise, the examiner and the gold standard (NZ) practiced measurement of various types of occlusal traits and orthodontic treatment need on study models based on the FDI/WHO method and Index of Orthodontic Treatment Need (Dental Health Component and Aesthetic Component) at University of Malaya. The study models consisted of a range of conditions representative of those that could be expected in the main study. There were discussions to resolve any difficulties in the diagnosis of different conditions. Any confusion was laid to rest and a standardisation exercise of the criteria was again carried out before the field calibration.

3.6.2 Field Clinical Calibration

The field calibration exercise was carried out on 30 secondary school children aged 14-years old, equally represented in gender from a school in Kuala Lumpur, Malaysia. Calibration was undertaken with the cooperation of the Kuala Lumpur school principal and Oral Health Division, the authority in charge of incremental dental care programme for the school. Children were chosen by a dental nurse of the school dental clinic.

General information such as name, age and gender were recorded. Each subject was given an identification number and seated on a dental chair. Both examiners wore gloves for the examination and changed after examination of each child. Disposable

mouth mirrors and DHC rulers used was disposed off also after the examination. The Cross Infection Control Policy of the Malaysian Dental Services was followed throughout the examination.

Inter-examiner calibration was carried out between the investigator and the gold standard. The measurements were made for occlusal variables and orthodontic treatment need included in the main study. The field research was monitored by an experienced oral epidemiologist throughout the session, the oral epidemiologist acted as the recorder for both examiners (Figure 3.25 and 3.26). Intra- examiner calibration was carried out by re-examination of the same subjects with a time lapse of one week apart, to eliminate the effect of memory bias.

Figures 3.25: Calibration exercise showing the gold standard (a) and recorder (b)

Figures 3.26: Calibration exercise showing the recorder (b) and examiner (c)

3.6.3 Calibration Results

Results of inter-examiner and intra-examiner calibration for all variables studied was analysed using the Cohen's Kappa statistic (Tables 3.3 to 3.7). Findings showed the Kappa statistics to be within 'substantial' agreement between examiners and within examiner.

Table 3.3: Results of inter-examiner calibration of occlusal traits

Variable	Inter-examiner calibration		Intra-examiner calibration	
	Kappa statistic	Strength of agreement	Kappa statistic	Strength of agreement
Impacted teeth	0.651	Substantial	0.651	Substantial
Hypodontia	1	Almost perfect	1	Almost perfect
Extracted teeth	1	Almost perfect	1	Almost perfect
Retained deciduous	1	Almost perfect	1	Almost perfect
Crowding maxilla	0.834	Very good	0.891	Very good
Crowding mandible	0.843	Very good	0.846	Very good
Diastema	1	Almost perfect	1	Almost perfect
Reverse overjet	1	Almost perfect	1	Almost perfect
Increased overjet	0.848	Very good	0.795	Substantial
Deepbite	0.766	Substantial	0.773	Substantial
Posterior crossbite	0.787	Substantial	0.787	Substantial
Molar relationship right side	0.682	Substantial	0.729	Substantial
Molar relationship left side	0.815	Very good	0.82	Very good

Table 3.4: Crosstabulation of inter-examiner calibration of Dental Health Component of IOTN measurement

Examiner	Gold standard examiner					Total
	No need	Little need	Moderate need	Great need	Very Great need	
No need	1	0	0	0	0	1
Little need	2	5	2	0	0	9
Moderate need	0	1	4	1	0	6
Great need	0	0	1	9	0	10
Very Great need	0	0	0	0	4	4
Total	3	6	7	11	4	30

Kappa = 0.693 (Substantial agreement)

Table 3.5: Crosstabulation of intra-examiner calibration of Dental Health Component of IOTN measurement

First examination	Second examination					Total
	No need	Little need	Moderate need	Great need	Very Great need	
No need	1	0	0	0	0	1
Little need	1	7	1	0	0	9
Moderate need	0	1	5	0	0	6
Great need	0	0	2	8	0	10
Very Great need	0	0	0	0	4	4
Total	2	8	8	8	4	30

Kappa = 0.780 (Substantial agreement)

Table 3.6: Crosstabulation of inter-examiner calibration of Aesthetic Component of IOTN measurement

Examiner	Gold standard examiner									Total
	grade 1	grade 2	grade 3	grade 4	grade 5	grade 6	grade 7	grade 8	grade 9	
grade 1	1	1	0	0	0	0	0	0	0	2
grade 2	1	9	1	0	0	0	0	0	0	11
grade 3	0	0	3	0	0	0	0	0	0	3
grade 4	0	0	0	1	1	0	0	0	0	2
grade 5	0	0	0	1	3	0	0	0	0	4
grade 6	0	0	0	0	0	1	0	0	0	1
grade 7	0	0	0	0	0	0	3	0	1	4
grade 8	0	0	0	0	0	0	0	1	0	1
grade 9	0	0	0	0	0	0	0	0	2	2
Total	2	10	4	2	4	1	3	1	3	30

Kappa = 0.755 (Substantial agreement)

Table 3.7: Crosstabulation of intra-examiner calibration of Aesthetic Component of IOTN measurement

First examination	Second examination									Total
	grade 1	grade 2	grade 3	grade 4	grade 5	grade 6	grade 7	grade 8	grade 9	
grade 1	1	1	0	0	0	0	0	0	0	2
grade 2	0	11	0	0	0	0	0	0	0	11
grade 3	0	0	2	1	0	0	0	0	0	3
grade 4	0	0	0	2	0	0	0	0	0	2
grade 5	0	0	0	0	3	1	0	0	0	4
grade 6	0	0	0	0	0	1	0	0	0	1
grade 7	0	0	0	0	0	0	4	0	0	4
grade 8	0	0	0	0	0	0	0	1	0	1
grade 9	0	0	0	0	0	0	0	0	2	2
Total	1	12	2	3	3	2	4	1	2	30

Kappa = 0.857 (Substantial agreement)

3.7 Pilot Study

A pilot study is a small experiment designed to gather information prior to the main study. The objectives of the pilot study were:

- To identify logistical problems and to study local students response to field examination before the main study exercise.
- To test on the adequacy of research forms used in recording the information, in terms of clarity and ease of understanding. This was important as the recorder in Yemen had never done this before.
- To familiarise the examiner with the school set up and subjects in the school.
- To estimate time taken for each examination.

3.7.1 Sampling and Examination Area

The pilot study was conducted in two secondary schools (one for males and another for female) in the Thamar governorate of Yemen. The schools were chosen by the State Education Authority without any influence from the examiner. These schools were not included in the main study.

The headmasters of the two schools were informed of the reason for the study and permission was obtained to conduct the examination. Sixty students (30 males and 30 females) aged 14 years were randomly selected by the school teachers in each school. All students were Yemenis, who never had orthodontic treatment or were currently not wearing an orthodontic appliance. All students were given information about the study verbally and final participation was voluntary.

3.7.2 Duplicate Examinations

Duplicate examination is recommended by the WHO (1997), to be carried out to assess shifts in diagnostic criteria over time. This recommended duplicate examination is being conducted on not less than 5% of the subjects. In this pilot study, the assistant who registered the students randomly selected ten students for repeat examination. The examiner was therefore not influenced by the selection of students for examination. The re-examination was done to test the intra-examiner consistency in conducting the clinical examination (Table 3.8).

3.7.3 Results of Pilot Study

The pilot study findings are shown in Appendices 14-20. During the pilot study the examiner had become more familiar with the forms to be used and conduct of the study. Time for examination was also noted, each student was found to require between 2 – 3 minutes on the average.

Table 3.8: Intra-examiner calibration of malocclusion as classified by Incisor, DHC and AC of IOTN

Subjects number	First Examination				Second Examination		
	Incisor Classification	DHC	AC		Incisor Classification	DHC	AC
1	Class I	3	4		Class I	2	4
2	Class II div 1	4	5		Class II div 1	4	5
3	Class II div 1	4	4		Class II div 1	3	4
4	Class II div 1	5	8		Class II div 1	5	8
5	Class I	2	2		Class I	2	2
6	Class I	1	1		Class I	1	2
7	Class II div 1	2	1		Class I	2	1
8	Class II div 1	4	5		Class II div 1	4	5
9	Class I	2	2		Class I	2	2
10	Class II div 1	4	7		Class II div 1	4	7

Kappa for Incisor Classification = 0.800 (Substantial agreement)
DHC of IOTN = 0.726 (Substantial agreement)
AC of IOTN = 0.878 (Substantial agreement)

3.8 Main Study Implementation

3.8.1 Examination Area

Examination and oral health assessment was performed according to the Basic Methods of Oral Health Survey of the World Health Organization (1997). The examination was carried out while the subject was seated in a straight-backed chair with the head resting on the back of the chair or where feasible a portable dental chair was used. The examination area was arranged in such a way that students entered at one point and will leave at another to prevent congestion around the examiner (Figure 3.27). Natural light was utilised as the light source for examination and portable light was only used to supplement natural light during examination when needed.

Figure 3.27: Position of the examiner, subject and recorder

3.8.2 General and Personal Information

Before any oral examination was done, general information consisting the date of examination, governorate, location (urban or rural), school name, and gender of the subjects was registered by the assistant. Each subject was given an identification number, and then interviewed individually to obtain personal information regarding their name, date of birth, place of birth, the origin of father and mother (Appendix 13). The subjects who were selected must not have any type of orthodontic treatment.

3.8.3 Clinical Examination

Clinical examination was carried out inside the schools and all examinations were performed by the investigator (R.A.A). Data of each subject was recorded in a standard form (Appendix 13) by the assistant (a Yemeni dentist volunteer) who had previously being trained by the investigator and took part in the pilot study. Each form was checked at the end of the study day by the investigator to ensure all information collected were complete. During the clinical examination, intra-examiner reproducibility was done by re-examing 10% of the Yemeni adolescents at the end of the session. The assistant who registered the subjects randomly selected subjects to be re-examined without examiner influence. The kappa statistic was used to analyse the results; the agreement of the examiner consistency was at least 0.6 which indicated substantial agreement.

3.9 Statistical Analyses

Information in the study forms were transferred into a spreadsheet, and subsequently entered into the SPSS (Statistical Package for Social Sciences) software version 15. Descriptive statistics were generated to check for discrepancies and consistencies in the overall data. Summary data to look at the distribution and subgroups were also generated. The demographic variables included were geographical zones, locations (urban and rural) and gender.

Further analysis was carried out to look at associations between the independent and dependent variables. Pearson Chi-square test were used to assess the statistical significance differences of geographical zones, locations and gender in the frequency distribution of categorical variables. If the assumption of data was not met or number of expected cell size was less than five, the Fisher's exact test was applied for association and comparison between two groups (location or gender). When a sample size of categorical variables was extremely small, the association test was not used because statistical significances even if observed might not be real or that which happened by chance (low power of study). The *P* value set was less than 0.05, considered as statistically significant. Correlations between examiner and subjects' assessment for orthodontic treatment need were calculated by using Kendall's tau correlation test.

In addition to the above, Cohen's Kappa test was also carried out to test for agreements in terms of examiner's consistency examination, for inter and intra examiner agreement. The interpretation of the scores was in accordance with the guidelines of Kappa statistic (Landis and Koch, 1977) as follows:

- Over 0.80 indicated Very good agreement.
- Over 0.60 indicated Substantial agreement.
- Over 0.40 indicated Moderate agreement.
- Over 0.20 indicated Fair agreement.
- 0.20 and less indicated Slight to Poor agreement.

CHAPTER FOUR

RESULTS

4.1 Occlusal Traits Based on FDI/WHO Method

Estimation of occlusal traits was made based on the FDI/WHO objective method of recording malocclusion which included dental discrepancies, space discrepancies and occlusal discrepancies.

4.1.1 Dental Discrepancies Assessment

Different forms of dental discrepancies were measured in the subjects examined. The most common dental discrepancies observed were impacted teeth (5.7%). Retained deciduous teeth (3.2%), missing teeth due to extraction or trauma (2.8%), congenitally absent teeth (2.2%) and supernumerary teeth (0.7%) totalled to slightly less than 10% of the sample (Figure 4.1).

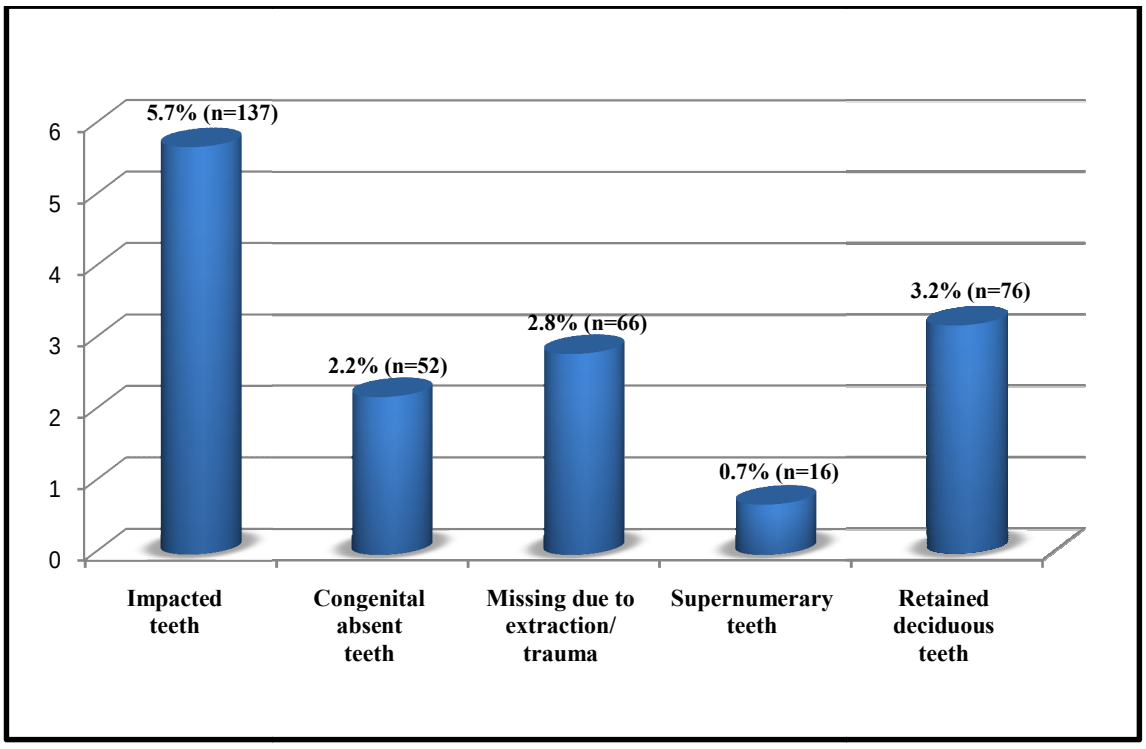


Figure 4.1: Prevalence of dental discrepancies of the sample

No statistical significance was found when dental discrepancies was analysed by geographical zones, location (urban and rural) and gender (Tables 4.1 & 4.2).

Table 4.1: Distribution of dental discrepancies by zones

Dentition Discrepancies		Zones (N= 2400)										*P*- value[a]
		North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)		
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Impacted teeth	Present	33	6.9	32	6.7	28	5.8	23	4.8	21	4.4	0.357
	None	447	93.1	448	93.3	452	94.2	457	95.2	459	95.6	
Congenitally absent teeth	Present	11	2.3	10	2.1	11	2.3	9	1.9	11	2.3	0.989
	None	469	97.7	470	97.9	469	97.7	471	98.1	469	97.7	
Missing teeth (extraction/ trauma)	Present	9	1.9	11	2.3	12	2.5	17	3.5	17	3.5	0.391
	None	471	98.1	469	97.7	468	97.5	463	96.5	463	96.5	
Supernumerary teeth	Present	2	0.4	4	0.8	1	0.2	6	1.2	3	0.6	*
	None	478	99.6	476	99.2	479	99.8	474	98.8	477	99.4	
Retained Deciduous teeth	Present	11	2.3	14	2.9	13	2.7	16	3.3	22	4.4	0.307
	None	469	97.7	466	97.1	467	97.3	464	96.7	458	95.4	

[a] Chi-square test conducted, level of significance at $P < 0.05$

*Inferential statistic was not conducted due to very small sample size in each category that will lead to very low power of study

Table 4.2: Distribution of dental discrepancies by location (urban & rural) and gender

Dental Discrepancies		Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
		Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
		n	*%*	*n*	*%*			*n*	*%*	*n*	*%*	
Impacted teeth	Present	73	6.1	64	5.3	0.482		74	6.2	63	5.2	0.379
	None	1127	93.9	1136	94.7			1126	93.8	1137	94.8	
Congenitally absent teeth	Present	30	2.5	22	1.8	0.267		27	2.2	25	2.1	0.782
	None	1170	97.5	1178	98.2			1173	97.8	1175	97.9	
Missing teeth (extraction/ trauma)	Present	28	2.3	38	3.2	0.261		40	3.3	26	2.2	0.081
	None	1172	97.7	1162	96.8			1160	96.7	1174	97.8	
Supernum-erary teeth	Present	6	0.5	10	0.8	0.453		9	0.7	7	0.6	0.628
	None	1194	99.5	1190	99.2			1191	99.3	1193	99.4	
Retained Deciduous teeth	Present	37	3.1	39	3.2	0.816		33	2.7	43	3.6	0.244
	None	1163	96.9	1161	96.8			1167	97.3	1157	96.4	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.1.1 Missing Permanent Teeth

Clinically observed impacted and congenitally absent teeth were found more on the maxilla, while missing teeth due to extraction or trauma were found mostly on the mandible. By tooth, the most frequently impacted tooth was the mandibular second premolar (31.7%) and the maxillary canine (19.3%). However, the most common congenitally absent tooth found was the maxillary lateral incisor (58.7%) and the mandibular second premolar (21.4%). In addition, extracted mandibular first molar was observed almost five times more than the maxillary first molar (Table 4.3).

Table 4.3: Distribution of missing permanent teeth

Dental discrepancies	Tooth type	Maxillary teeth		Mandibular teeth		Total	
		n	%	*n*	%	*n*	%
Impacted teeth	Central incisor						
	Lateral incisor	8	5.5			8	5.5
	Canine	28	19.3	7	4.8	35	24.1
	First premolar			3	2.1	3	2.1
	Second premolar	21	14.5	46	31.7	67	46.2
	First molar						
	Second molar	19	13.1	13	9	32	22.1
	All	76	52.4	69	47.6	145	100
Congenitally absent teeth	Central incisor			4	5.3	4	5.3
	Lateral incisor	44	58.7	4	5.3	48	64
	Canine						
	First premolar						
	Second premolar	7	9.3	16	21.4	23	30.7
	First molar						
	Second molar						
	All	51	68.0	24	32.0	75	100
Missing teeth (extraction/trauma)	Central incisor	8	11.3	2	2.8	10	14.1
	Lateral incisor	5	7.0			5	7.0
	Canine	4	5.6			4	5.6
	First premolar	7	9.9	3	4.2	10	14.1
	Second premolar	1	1.4	5	7.0	6	8.5
	First molar	6	8.5	28	39.4	34	47.9
	Second molar	2	2.8			2	2.8
	All	33	46.6	38	53.4	71	100

4.1.1.2 Supernumerary and Retained Deciduous Teeth

Supernumerary teeth were found more on the maxilla than mandible. Analysis showed that the maxillary lateral incisor (50%) and maxillary central incisor areas (31.2%) were the most common supernumerary teeth. The most frequently retained deciduous tooth observed was the mandibular second molar (41.8%) which occurred approximately (1.6) times more than maxillary second molar (Table 4.4).

Table 4.4: Distribution of supernumerary, partially erupted and retained deciduous teeth

Dental discrepancies	Tooth type	Maxillary teeth		Mandibular teeth		Total	
		n	%	*n*	%	*n*	%
Supernumerary teeth	Central incisor	5	31.2	2	12.5	7	43.7
	Lateral incisor	8	50.0			8	50.0
	Canine						
	First premolar						
	Second premolar	1	6.3			1	6.3
	First molar						
	Second molar						
	All	14	87.5	2	12.5	16	100
Retained deciduous teeth	Central incisor (A)	1	1.3	2	2.5	3	3.8
	Lateral incisor (B)	1	1.3	2	2.5	3	3.8
	Canine (C)	17	21.5	3	3.8	20	25.3
	First molar (E)						
	Second molar (D)	20	25.3	33	41.8	53	67.1
	All	39	49.4	40	50.6	79	100

4.1.2 Space Discrepancies Assessment

Space discrepancies assessment included crowding, spacing and maxillary midline diastema. The measurements of crowding and spacing were divided into three groups:

- 2 mm and more
- Less than 2 mm
- None

4.1.2.1 Crowding

Crowding was observed to be more in the mandible (48.7%) than in the maxilla (26%). When severity of crowding in the maxilla and mandible was cross tabulated, slightly over a quarter of the sample (27.8%) was recorded to have crowding of ≥ 2 mm, while crowding of < 2 mm was found in 25.5% of the sample. Besides, it was observed that 1120 subjects representing 46.7% of the sample were without any kind of crowding in the maxilla or mandible (Table 4.5).

Table 4.5: Crosstabulation between maxillary and mandibular crowding

Crowding		Maxilla						Total	
		None		< 2 mm		≥ 2 mm			
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Mandible	None	1120	46.7	74	3.1	37	1.6	*1231*	*51.3*
	< 2 mm	451	18.8	86	3.6	30	1.2	*567*	*23.6*
	≥ 2 mm	205	8.5	243	10.1	154	6.4	*602*	*25.1*
Total		*1776*	*74.0*	*403*	*16.8*	*221*	*9.2*	*2400*	*100*

Red — Crowding of 2 mm and more

Orange — Crowding of less than 2 mm

White — No crowding in maxilla and mandible, excluded the total

4.1.2.1.1 Maxillary Crowding

The distribution of crowding in the maxilla accounted for 26% of those with discrepancies. In terms of severity, crowding 2 mm or more in the maxilla (9.2%) differed significantly between the five zones. Findings showed that the north (mountains) zone (13.5%) and east zone (desert) (12.3%) had a higher percentage pattern of crowding (Tables 4.6).

When analysed by location, the overall Chi-square test did not show any significant differences between urban and rural adolescents with regards to maxillary crowding. The prevalence of crowding in the maxilla was also found to be not different in males than females (26.3% versus 25.8%, respectively) (Table 4.7).

Table 4.6: Distribution of maxillary crowding by zones

Maxillary crowding		Zones										Total (N= 2400)		*P*- value[a]
		North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
		n	*%*	n	%	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 2 mm	65	13.5	40	8.3	22	4.6	59	12.3	35	7.3	221	9.2	0.000
Mild	< 2 mm	74	15.4	96	20	78	16.3	86	17.9	69	14.4	2179	90.8	
No crowding		431	71	344	71.6	380	79.2	335	69.9	376	78.4			

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.7: Distribution of maxillary crowding by location (urban & rural) and gender

Maxillary crowding		Location				Total (N= 2400)		*P*- value[a]		Gender				Total (N= 2400)		*P*- value[a]
		Urban (n= 1200)		Rural (n= 1200)						Male (n= 1200)		Female (n= 1200)				
		n	*%*	*n*	*%*	*n*	*%*			*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 2 mm	121	10.1	100	8.4	221	9.2	0.138		103	8.6	118	9.9	221	9.2	0.290
Mild	< 2 mm	190	15.8	213	17.8	2179	90.8			212	17.7	191	15.9	2179	90.8	
No crowding		889	74.1	887	74					885	73.7	891	74.2			

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.2.1.2 Mandibular Crowding

Analysis of overall distribution of crowding in the mandible showed that crowding occurred in 48.7% of the sample. The prevalence of crowding of ≥ 2 mm were found in 25.1% of the sample. When considered by zones, finding also showed slightly more than a quarter (28.3%) of the Yemeni 14- year-olds in east (desert), (27.5%) in the north (mountains) and (25.8%) in the middle (plateaus) zones had the highest proportions of crowding. The differences found were statistically significant *P*= 0.026 (Table 4.8).

Analysis by location showed almost equal proportions of the urban and rural adolescents had crowding of ≥ 2 mm. A similar pattern was also observed among male and female adolescents (Table 4.9).

Table 4.8: Distribution of mandibular crowding by zones

Mandibular crowding		Zones										Total (N= 2400)		*P*- value[a]
		North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Increased	≥ 2 mm	132	27.5	113	23.5	124	25.8	136	28.3	97	20.2	602	25.1	0.026
Mild	< 2 mm	99	20.6	130	27.1	95	19.8	118	24.6	125	26.0	1798	74.9	
No crowding		249	51.9	237	49.3	261	54.3	226	47.0	258	53.7			

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.9: Distribution of mandibular crowding by location (urban & rural) and gender

Mandibular crowding		Location				Total (N= 2400)		*P*- value[a]		Gender				Total (N= 2400)		*P*- value[a]
		Urban (n= 1200)		Rural (n= 1200)						Male (n= 1200)		Female (n= 1200)				
		n	%	*n*	%	*n*	%			*n*	%	*n*	%	*n*	%	
Increased	≥ 2 mm	302	25.2	300	25.0	602	25.1	0.925		309	25.6	293	24.4	602	25.1	0.451
Mild	< 2 mm	285	23.6	282	23.5	1798	74.9			269	22.4	298	24.8	1798	74.9	
No crowding		613	48.1	573	51.6					622	51.9	609	50.8			

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.2.2 Spacing

Contrary to crowding, the distribution of spacing in the sample population was found more in the maxilla (9.8%) than in the mandible (3.4%). Table 4.10, presented the crosstabulation severity of spacing in the maxilla and mandible. Analysis showed that 2.9% had spacing of ≥ 2 mm, and 9.1% of the sample had spacing of < 2 mm either in the mandible or maxilla or in both jaws.

Table 4.10: Crosstabulation between maxillary and mandibular spacing

Spacing		Maxilla						Total	
		None		< 2 mm		≥ 2 mm			
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Mandible	None	2111	88.0	162	6.8	46	1.9	*2319*	*96.6*
	< 2 mm	53	2.2	3	0.1	7	0.3	*63*	*2.6*
	≥ 2 mm	2	0.1	13	0.5	3	0.1	*18*	*0.8*
Total		*2166*	*90.3*	*178*	*7.4*	*56*	*2.3*	*2400*	*100*

Red	Spacing of 2 mm and more
Orange	Spacing of less than 2 mm
White	No spacing in maxilla and mandible, excluded the total

4.1.2.2.1 Maxillary and Mandibular Spacing

Maxillary spacing (≥ 2 mm) accounted for 2.3% of the sample. The differences of spacing in the maxilla between zones was found to be statistically significant at *P*= 0.041. Finding showed maxillary spacing was more prevalent among the south (coastal) (3.9%), west (coastal and island) (2.7%) and middle (plateaus) (2.3%) zone adolescents (Table 4.11). Analysis by location and gender in general, did not show much difference in distribution. Although not statistically significant, a slightly higher proportion of female (2.8%) than male (1.9%) adolescents were found to have maxillary spacing of 2 mm and more (Table 4.12).

Only a small proportion (0.8%) of the sample had severe mandibular spacing. Analysis by zones showed a similar distribution pattern (Table 4.13). Although spacing of ≥ 2 mm only occurred in a small proportion, slightly more in rural (2.6% vs. 2.1%) and females (2.8% vs. 1.9%) 14 year-olds were affected (Table 4.14).

Table 4.11: Distribution of maxillary spacing between zones

Maxillary spacing		Zones										Total (N= 2400)		*P*- value[a]
		North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 2 mm	6	1.2	19	3.9	11	2.3	7	1.5	13	2.7	56	2.3	0.041
Mild	< 2 mm	22	4.6	43	8.9	26	5.4	32	6.7	55	11.5	2344	97.7	
No spacing		452	94.1	418	87.1	443	92.4	441	91.9	412	85.9			

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.12: Distribution of maxillary spacing between location (urban & rural) and gender

Maxillary spacing		Location				Total (N= 2400)		*P*- value[a]	Gender				Total (N= 2400)		*P*- value[a]
		Urban (n= 1200)		Rural (n= 1200)					Male (n= 1200)		Female (n= 1200)				
		n	*%*	*n*	*%*	*n*	*%*		*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 2 mm	25	2.1	31	2.6	56	2.3	0.417	23	1.9	33	2.8	56	2.3	0.176
Mild	< 2 mm	80	6.7	98	8.2	2344	97.7		83	6.9	95	7.9	2344	97.7	
No spacing		1095	91.2	1071	89.2				1094	91.2	1072	89.3			

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.13: Distribution of mandibular spacing between zones

Mandibular spacing		Zones										Total (N= 2400)		*P*- value
		North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 2 mm	4	0.8	4	0.8	4	0.8	2	0.4	4	0.8	18	0.8	*
Mild	< 2 mm	6	1.3	13	2.7	12	2.5	15	3.1	17	3.5	2382	99.2	
No spacing		470	97.9	463	96.5	464	96.7	463	96.5	459	95.7			

*Inferential statistic was not conducted due to very small sample size in each category that will lead very low power of study

Table 4.14: Distribution of mandibular spacing between location (urban & rural) and gender

Mandibular spacing		Location				Total (N= 2400)		*P*- value[a]		Gender				Total (N= 2400)		*P*- value[a]
		Urban (n= 1200)		Rural (n= 1200)						Male (n= 1200)		Female (n= 1200)				
		n	*%*	*n*	*%*	*n*	*%*			*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 2 mm	5	0.4	13	1.1	18	0.8	0.095		8	0.7	10	0.8	18	0.8	0.814
Mild	< 2 mm	31	2.6	32	2.7	2382	99.2			30	2.5	33	2.8	2382	99.2	
No spacing		1164	96.9	1155	96.3					1162	96.7	1157	96.4			

[a] Fisher's Exact test conducted, level of significance at $P < 0.05$

4.1.2.3 Maxillary Midline Diastema

Analysis of maxillary midline diastema was carried out on 2392 records. Eight subjects were excluded because of extraction of central incisors. Maxillary midline diastema was found in 5.4% of the sample examined **(**Table 4.15). Findings showed that the higher prevalence of diastema was in the north (mountains) zone (8.5%) followed by middle (plateaus) (6.1%) and west (coastal and island) (5%) zones. These inter-zones differences were found to be statistically significant at *P*= 0.002 (Table 4.15).

Analysis by location and gender showed a slightly higher proportion of urban (5.9%) adolescents having maxillary midline diastema, while a similar distribution pattern was observed between genders. The differences were found to be not statistically significant **(**Table 4.15).

Table 4.15: Association of maxillary diastema between demographic variables

Demographic variables		Maxillary diastema				*P*- value[a]
		Present		None		
		n	*%*	*n*	*%*	
Zones	North	41	8.5	439	91.5	0.002
	South	13	2.7	467	97.3	
	Middle	29	6.1	450	93.9	
	East	23	4.8	454	95.2	
	West	24	5.0	452	95.0	
Location	Urban	71	5.9	1126	94.1	0.284
	Rural	59	4.9	1136	95.1	
Gender	Male	65	5.4	1129	94.6	0.528
	Female	65	5.4	1133	94.6	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.3 Occlusal Discrepancies Assessment

Assessment of occlusal discrepancies included antero-posterior, vertical and transversal relationship of occlusion.

4.1.3.1 Occlusal Discrepancies in Antero-posterior Relationship

Anterio-posterior relationship of occlusion measurements included the modified Angle Classification for molar relationship, maxillary and reverses overjet and anterior crossbite.

4.1.3.1.1 Molar Relationship

Of the sample, molar occlusion of 44 subjects was not recordable because of extracted or badly broken first molars. Analysis was made on a total sample of 2356 subjects. Crosstabulation of the right and left sides molar relationship (Table 4.16) showed that symmetrical molar relationship was observed in 88.7% of the sample. Symmetrical (bilateral) Class I was found in 58.7% of the sample while bilateral Class II and Class III relationship were found to be 27.3% and 2.7% of the sample, respectively. Asymmetrical molar relationship thus was found in only 11.3% of the sample (Class I/Class II in 9.4%, Class I/Class III in 1.4% and Class II/Class III in 0.4% of the sample).

Table 4.16: Crosstabulation of right and left molar relationship classes

Molar relationship classes		Left Side						Total	
		Class I		Class II		Class III			
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Right Side	Class I	1384	58.7	108	4.6	19	0.8	*1511*	*64.1*
	Class II	114	4.9	644	27.3	8	0.3	*766*	*32.5*
	Class III	15	0.6	1	0.04	63	2.7	*79*	*3.4*
Total		*1513*	*64.2*	*753*	*32.0*	*90*	*3.8*	*2356*	*100*

Orange — Symmetrical (bilateral) molar relationship

Red — Asymmetrical molar relationship

A) Distribution of Molar Relationship Discrepancy

Molar relationship of Class II (distal) and Class III (mesial) on right or left sides of occlusion was categorised as 'discrepancy' when there was deviation of at least one-half cusp (½ unit) width distally or mesially to Class I.

Class II molar relationship discrepancy was found to be almost equally distributed on the right (17.4%) and left (15.8%) sides of occlusion in the sample. When considered by zone, Class II molar relationship discrepancy was observed mostly in the south (coastal) zone (right 21.4%, left 19.2%) and east (desert) zone adolescents (right 19.3%, left 17.6%) while the lowest were found in adolescents living in the west (coastal and island) zone (right 15.2%, left 11.6%). The difference was found to be statistically significant at right (P= 0.031) and left (P= 0.019) (Table 4.17).

Analysis by location and gender showed almost equal proportions (Table 4.18). Females were however observed to have slightly more Class III molar relationship discrepancy on both sides of the occlusion (right 1.5%, left 1.9%) than males (right 0.9%, left1%).

Table 4.17: Distribution of molar relationship discrepancy in right and left sides of occlusion by zones

Molar relationship of ½ unit and more			Zones (N= 2356)										*P*- value[a]
			North (n= 468)		South (n= 473)		Middle (n= 471)		East (n= 471)		West (n= 473)		
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Right side	Class II	Present	75	16.0	101	21.4	70	14.9	91	19.3	72	15.2	0.031
		None	393	84.0	372	78.6	401	85.1	380	80.7	401	84.8	
	Class III	Present	12	2.6	2	0.4	4	0.8	8	1.7	2	0.4	*
		None	456	97.4	471	99.6	467	99.2	463	98.3	471	99.6	
Left side	Class II	Present	72	15.4	91	19.2	71	15.1	83	17.6	55	11.6	0.019
		None	396	84.6	382	80.8	400	84.9	388	82.4	418	88.4	
	Class III	Present	11	2.4	3	0.6	10	2.1	9	1.9	2	0.4	*
		None	457	97.6	470	99.4	461	97.9	462	98.1	471	99.6	

[a] Chi-square test conducted, level of significance at $P < 0.05$

*Inferential statistic was not conducted due to very small sample size in each category that will lead to very low power of study

Table 4.18: Distribution of molar relationship discrepancy in right and left sides of occlusion by location (urban & rural) and gender

Molar relationship of ½ unit and more			Location (N= 2356)				*P*- value[a]	Gender (N= 2356)				*P*- value[a]
			Urban (n= 1186)		Rural (n= 1170)			Male (n= 1172)		Female (n= 1148)		
			n	*%*	*n*	*%*		*n*	*%*	*n*	*%*	
Right side	Class II	Present	197	16.6	212	18.1	0.334	209	17.8	200	16.9	0.547
		None	989	83.4	958	81.9		963	82.2	984	83.1	
	Class III	Present	13	1.1	15	1.3	0.677	10	0.9	18	1.5	0.135
		None	1173	98.9	1155	98.7		1162	99.1	1166	98.5	
Left side	Class II	Present	190	16	182	15.6	0.757	191	16.3	181	15.3	0.502
		None	996	84	988	84.4		981	83.7	1003	84.7	
	Class III	Present	18	1.5	17	1.5	0.897	12	1.0	23	1.9	0.065
		None	1168	98.5	1153	98.5		1160	99	1161	98.1	

[a] Chi-square test conducted, level of significance at $P < 0.05$

B) Distribution of Units Class II Molar Relationship

In general, only a small proportion had full Class II molar relationship discrepancy (right 13.4%, left 15%). Majority had a Class II ½ (right 74.6%, left 73.7%) molar relationship across all zones (Tables 4.19).

Table 4.19: Distribution of units Class II molar relationship by zones

Class II units		Zones										Total	
		North		South		Middle		East		West			
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Right Side	½ unit	56	13.7	79	19.3	50	12.2	67	16.4	53	12.9	305	74.6
	¾ unit	9	2.2	9	2.2	10	2.4	13	3.2	8	2.0	49	12.0
	Full unit	10	2.4	13	3.2	10	2.4	11	2.7	11	2.7	55	13.4
	Total	75	18.3	101	24.7	70	17.0	91	22.3	72	17.6	409	100
Left side	½ unit	59	15.9	64	17.2	50	13.4	61	16.4	40	10.8	274	73.7
	¾ unit	4	1.1	12	3.2	11	3.0	8	2.2	7	1.9	42	11.3
	Full unit	9	2.4	15	4.0	10	2.7	14	3.8	8	2.2	56	15.0
	Total	72	19.4	91	24.4	71	19.1	83	22.4	55	14.9	372	100

4.1.3.1.2 Overjet

Majority of the adolescents (90.9%) in this study had normal overjet < 6 mm. Maxillary overjet of ≥ 6 mm was found in 9.1% of the sample (Table 4.20). On the other hand, a smaller proportion had reverse overjet (2.3%) (Table 4.22).

The examination of maxillary overjet was carried out on 2400 subjects. Analysis of maxillary overjet was done on 2297 of the sample (excluding all cases of anterior crossbite and reverse overjet). Increased overjet when examined by zones was observed mostly in adolescents living in the south (coastal) (11.5%) and north (mountains) zone (9.7%) (Table 4.20).

Analysis also showed that slightly more urban (9.6%) than rural (8.7%) and, slightly more male (9.6%) than female (8.6%) adolescents had increased overjet (Table 4.21). The distribution of maxillary increased overjet severity by zones, location and gender differences when tested by Chi- square test were found to be statistically not significant

Table 4.20: Distribution of maxillary overjet of the sample by zones

Maxillary overjet		Zones										Total (N= 2297)		*P*- value[a]
		North (n= 453)		South (n= 462)		Middle (n= 465)		East (n= 450)		West (n= 467)				
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 9 mm	18	4.0	23	5.0	20	4.3	16	3.6	12	2.6	209	9.1	0.083
	6 to < 9 mm	26	5.7	30	6.5	24	5.2	23	5.1	17	3.6			
Acceptable	< 6 mm	409	90.3	409	88.5	421	90.5	411	91.3	438	93.8	2088	90.9	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.21: Distribution of maxillary overjet of the sample by location (urban & rural) and gender

Maxillary overjet		Location				Total (N= 2297)		*P*- value[a]		Gender				Total (N= 2297)		*P*- value[a]
		Urban (n= 1158)		Rural (n= 1139)						Male (n= 1146)		Female (n= 1151)				
		n	*%*	*n*	*%*	*n*	*%*			*n*	*%*	*n*	*%*	*n*	*%*	
Increased	≥ 9 mm	43	3.8	46	4.0	209	9.1	0.598		39	3.4	50	4.3	209	9.1	0.406
	6 to < 9 mm	67	5.8	53	4.7					71	6.2	49	4.3			
Acceptable	< 6 mm	1048	90.9	1040	91.3	2088	90.9			1036	90.4	1052	91.4	2088	90.9	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Reverse overjet was observed more in adolescents living in the east (desert) and north (mountains) zones (3.1% each). On the other hand, the smallest amount of reverse overjet was observed in the south (coastal) zone (1.4%) adolescents (Table 4.22). Analysis also showed that more rural (2.9%) than urban (1.8%) adolescents had reversed overjet (Table 4.23). The differences of reverse overjet by all demographic variables were found statistically not significant ($P > 0.05$).

Table 4.22: Distribution of reverse overjet by zones

Reverse Overjet	Zones										Total (N= 2400)		*P*-value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Present	15	3.1	7	1.4	9	1.8	15	3.1	10	2.0	56	2.3	0.306
None	465	96.9	473	98.6	471	98.2	465	96.9	470	98	2344	97.7	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.23: Distribution of reverse overjet by location (urban & rural) and gender

Reverse Overjet	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	%	*n*	%			*n*	%	*n*	%	
Present	21	1.8	35	2.9	0.058		27	2.2	29	2.4	0.787
None	1179	98.2	1165	97.1			1173	97.8	1171	97.6	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.3.1.3 Anterior Crossbite

A small proportion (n=47, 2%) of the sample was found to have anterior crossbite. Of these, anterior crossbite involving one tooth was observed to be the most common (1.1%), while anterior crossbite involving two or three teeth were observed in 0.9% of those affected. Distribution of anterior crossbite by demographic variables was shown in Tables 4.24 and 4.25.

Table 4.24: Distribution of anterior crossbite of the sample according to zones

Anterior crossbite	Zones										Total (N= 2400)	
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)			
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
3 teeth	1	0.2	2	0.4	2	0.4	3	0.6	1	0.2	9	0.4
2 teeth	4	0.8	1	0.2	1	0.2	5	1.0	1	0.2	12	0.5
1 tooth	7	1.5	8	1.6	3	0.6	7	1.5	1	0.2	26	1.1
Total	12	2.5	11	2.3	6	1.2	15	3.1	3	0.6	47	2.0

Table 4.25: Distribution of anterior crossbite according to location (urban & rural) and gender

Anterior crossbite	Location (N= 2400)					Gender (N= 2400)			
	Urban (n= 1200)		Rural (n= 1200)			Male (n= 1200)		Female (n= 1200)	
	n	*%*	*n*	*%*		*n*	*%*	*n*	*%*
3 teeth	4	0.3	5	0.4		5	0.4	4	0.3
2 teeth	7	0.6	5	0.4		8	0.7	4	0.3
1 tooth	10	0.8	16	1.3		14	1.2	12	1.0
Total	21	1.7	26	2.1		27	2.3	20	1.6

Finding by zones showed that anterior crossbite was more prevalent in the east (desert) zone adolescents (3.1%) followed by those in the north (mountains) (2.5%) and smaller proportion of anterior crossbite was observed in the west (coastal and island) zone (Table 4.26). Analysis also found almost equal proportion of anterior crossbite between location and gender. There were no gross differences between demographic variables in the prevalence of anterior crossbite (Table 4.26).

Table 4.26: Association of anterior crossbite with various demographic variables

Demographic variables		Anterior crossbite				*P*- value[a]
		Present		None		
		n	*%*	*n*	*%*	
Zones	North	12	2.5	468	97.5	*
	South	11	2.3	469	97.7	
	Middle	6	1.2	474	98.8	
	East	15	3.1	465	96.9	
	West	3	0.6	477	99.4	
Location	Urban	21	1.7	1179	98.3	0.461
	Rural	26	2.1	1174	97.9	
Gender	Male	27	2.3	1173	97.7	0.302
	Female	20	1.6	1180	98.4	

[a] Chi-square test conducted, level of significance at $P < 0.05$

*Inferential statistic was not conducted due to very small sample size in each category that will lead to very low power of study

4.1.3.2 Occlusal Discrepancies in Vertical Relationship

Vertical discrepancy measurements of occlusion included vertical anterior segment relationship (overbite and anterior openbite) and vertical buccal segments relationship (posterior openbite)

4.1.3.2.1 Overbite

Analysis of overbite was carried out in 2292 of the sample, excluding all cases of anterior openbite. Findings showed that majority of the sample (89.7%) had acceptable overbite (< 2/3 overlap), while deepbite was found in 10.3%. The prevalence of deepbite was found more (13.4%) in the middle (plateaus) and (11.8%) in the west (coastal and island) zones, with subjects from the east (desert) and north (mountains) zones (8.4% and 7.8% respectively) having smaller proportions affected. The Chi-square test showed statistically significant differences between zones at P= 0.027, (Table 4.27).

Slightly more cases of deepbite were found among the males (11.1%) than females (9.4%). On the other hand, the prevalence of deepbite was found to be slightly more in the rural areas than urban. Statistical analysis on location and gender differences were found to be of no significant differences (Table 4.28).

Table 4.27: Association of overbite of the sample between zones

Overbite		Zones										Total (N= 2292)		*P*- value[a]
		North (n= 462)		South (n= 466)		Middle (n= 462)		East (n= 443)		West (n= 459)				
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Deep bite	3/3 and more	16	3.5	9	1.9	15	3.2	14	3.2	15	3.3	236	10.3	0.027
	2/3 to < 3/3	20	4.3	38	8.2	47	10.2	23	5.2	39	8.5			
Acceptable	< 2/3	426	92.2	419	89.9	400	86.6	406	91.6	405	88.2	2056	89.7	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.28: Association of overbite of the sample between location (urban & rural) and gender

Overbite		Location				Total (N= 2292)		*P*- value[a]		Gender				Total (N= 2292)		*P*- value[a]
		Urban (n= 1148)		Rural (n= 1144)						Male (n= 1157)		Female (n= 1135)				
		n	%	*n*	%	*n*	%			*n*	%	*n*	%	*n*	%	
Deep bite	3/3 and more	33	2.9	36	3.1	236	10.3	0.206		42	3.6	27	2.4	236	10.3	0.175
	2/3 to < 3/3	76	6.6	91	8.0					87	7.5	80	7.0			
Acceptable	< 2/3	1039	90.5	1017	88.9	2056	89.7			1028	88.9	1028	90.6	2056	89.7	

[a] Chi-square test conducted level of significance at $P < 0.05$

4.1.3.2.2 Anterior Openbite

Prevalence of anterior openbite was observed in 4.5% of the Yemeni adolescents. The distribution of anterior openbite by demographic variables was found to be statistically significant between zones and gender ($P< 0.05$), while almost equal proportion was observed by location. Anterior openbite was found higher prevalence 7.7% and 4.3% in the east (desert) and west (coastal and island) zone adolescents respectively, while the smallest proportion (2.9%) was observed in the south (coastal) zone adolescents (Table 4.29). The distribution of anterior openbite according to gender showed female had a higher proportion (5.4%) than male (3.6%) (Table 4.30).

Table 4.29: Distribution of anterior openbite by zones

Anterior openbit	Zones										Total (N= 2400)		*P*-value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Present	18	3.8	14	2.9	18	3.8	37	7.7	21	4.3	108	4.5	0.004
None	462	96.2	466	97.1	462	96.2	443	92.3	459	95.7	2292	95.5	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.30: Distribution of anterior openbite by location (urban & rural) and gender

Anterior openbit	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	*%*	*n*	*%*			*n*	*%*	*n*	*%*	
Present	52	4.4	56	4.7	0.694		43	3.6	65	5.4	0.030
None	1148	95.6	1144	95.3			1157	96.4	1135	94.6	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.3.2.3 Posterior Openbite

Vertical relationship of the occlusion on the buccal segments (posterior openbite) was found in 2.9% among the 14 year-old Yemeni adolescents. The distribution of posterior openbite by demographic variables was found to be statistically significant only between gender at $P = 0.022$, (Table 4.31). Findings showed that females (3.8%) had more posterior openbite than males (2.2%) (Table 4.32).

Table 4.31: Distribution of posterior openbite by zones

Posterior openbite	Zones										Total (N= 2400)		*P*-value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Present	14	2.9	9	1.8	11	2.2	23	4.9	14	2.9	71	2.9	0.080
None	466	97.1	471	98.2	469	97.8	457	95.1	466	97.1	2392	97.1	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.32: Distribution of posterior openbite by location (urban & rural) and gender

Posterior openbite	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	*%*	*n*	*%*			*n*	*%*	*n*	*%*	
Present	30	2.5	41	3.4	0.185		26	2.2	45	3.8	0.022
None	1170	97.5	1159	96.6			1174	97.8	1155	96.2	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.3.3 Occlusal Discrepancies in Transversal Relationship

4.1.3.3.1 Posterior Crossbite

One hundred and twenty six (5.2%) of the sample were found to have posterior crossbite. Of these, bilateral crossbite was found in 1.5%, while unilateral posterior crossbite was observed in 3.7% (unilateral right 2.4% and left 1.3%) of the sample. Distribution of bilateral and unilateral posterior crossbite by demographic variables is as shown in Tables 4.33 and 4.34.

Table 4.33: Distribution of posterior crossbite by zones

Posterior crossbite	Zones										Total (N=2400)	
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)			
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Bilateral	11	2.3	10	2.1	4	0.8	6	1.3	4	0.8	35	1.5
Unilateral Right	13	2.7	7	1.5	13	2.7	18	3.8	7	1.5	58	2.4
Unilateral Left	8	1.7	2	0.4	8	1.7	12	2.5	3	0.6	33	1.3
Total	32	6.7	19	4.0	25	5.2	36	7.5	14	2.9	126	5.2

Table 4.34: Distribution of posterior crossbite according to location (urban & rural) and gender

Posterior crossbite	Location (N= 2400)					Gender (N= 2400)			
	Urban (n= 1200)		Rural (n= 1200)			Male (n= 1200)		Female (n= 1200)	
	n	*%*	*n*	*%*		*n*	*%*	*n*	*%*
Bilateral	18	1.5	17	1.4		14	1.2	21	1.8
Unilateral Right	22	1.8	36	3.0		33	2.8	25	2.1
Unilateral Left	14	1.2	19	1.6		17	1.4	16	1.3
Total	54	4.5	72	6.0		64	5.3	62	5.2

Analysis by zones showed posterior crossbite to be more prevalent in the east (desert) (7.5%) and north (mountains) (6.7%) zones followed by the middle (plateaus) (5.2%) and south (coastal) (4%) zones, while the lowest value was in the west zone (2.9%). The differences was found to be statistically significant at *P*= 0.008 (Table 4.35).

The prevalence of posterior crossbite was also found to be slightly higher (6%) in the rural than in the urban (4.5%) adolescents. Equal proportion of male (5.3%) and female (5.2%) were found to have the condition (Table 4.35).

Table 4.35: Association of posterior openbite between demographic variables

Demographic variables		Posterior crossbite				*P*- value[a]
		Present		None		
		n	%	*n*	%	
Zones	North	32	6.7	448	93.3	0.008
	South	19	4.0	461	96.0	
	Middle	25	5.2	455	94.8	
	East	36	7.5	444	92.5	
	West	14	2.9	466	97.1	
Location	Urban	54	4.5	1146	95.5	0.099
	Rural	72	6.0	1128	94.0	
Gender	Male	64	5.3	1136	94.7	0.855
	Female	62	5.2	1138	94.8	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.1.3.3.2 Scissor bite

Finding of scissor bite was found in 2.7% of the sample. The differences of scissor bite between demographic variables were found to be not statistically significant *P*> 0.05, (Tables 4.36 and 4.37).

Table 4.36: Distribution of scissor bite by zones

Scissor bite	Zones										Total (N= 2400)		*P*-value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Present	17	3.5	9	1.8	15	3.1	15	3.1	10	2.1	66	2.7	0.434
None	463	96.5	471	98.2	465	96.9	465	96.9	470	97.9	2334	97.2	

[a] Chi-square test conducted level of significance at $P < 0.05$

Table 4.37: Distribution of scissor bite by location (urban & rural) and gender

Scissor bite	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	%	*n*	%			*n*	%	*n*	%	
Present	30	2.5	36	3.0	0.454		37	3.1	29	2.4	0.318
None	1170	97.5	1164	97.0			1163	96.9	1171	97.6	

[a] Chi-square test conducted level of significance at $P < 0.05$

4.2 Additional Occlusal Traits Observed

Occlusal traits observed in the clinical examination but not measured by FDI/WHO conventional method were partially erupted teeth, canine relationship and bimaxillary protrusion.

4.2.1 Partially Erupted Teeth

The prevalence of partially erupted teeth was found in 6.5% of the Yemeni adolescents. Analysis also showed 157 partially erupted teeth were seen in the same number of subjects. The most common partially erupted tooth observed was the maxillary canine (34.4%) followed by the mandibular canine (19.1%) and mandibular second premolar (16%) (Table 4.38).

Analysis by zones showed statistical significant differences for partially erupted teeth. The distribution was found more with adolescents living in north (mountains) zone (11%) and smallest proportion in the west (coastal and island) zone (3.8%) adolescents. Analysis of the distribution by location and gender did not show much differences (Table 4.39).

Table 4.38: Distribution of partially erupted teeth for the jaw

	Tooth type	Maxillary teeth		Mandibular teeth		Total	
		n	*%*	*n*	*%*	*n*	*%*
Partially erupted teeth	Central incisor						
	Lateral incisor						
	Canine	54	34.4	30	19.1	84	53.5
	First premolar	16	10.2	11	7.0	27	17.2
	Second premolar	12	7.6	25	16.0	37	23.6
	First molar						
	Second molar	6	3.8	3	1.9	9	5.7
	All	88	56	69	44	157	100

Table 4.39: Distribution of partially erupted teeth between demographic variables

Demographic variables		Partially erupted teeth				*P*- value[a]
		Present		None		
		n	%	*n*	%	
Zones	North	53	11.0	427	89	0.000
	South	36	7.5	444	92.5	
	Middle	27	5.6	453	94.4	
	East	23	4.8	457	95.2	
	West	18	3.7	462	96.3	
Location	Urban	86	7.2	1114	92.8	0.216
	Rural	71	5.9	1129	94.1	
Gender	Male	82	6.8	1118	93.2	0.563
	Female	75	6.2	1125	93.8	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.2.2 Canine Relationship

Of the sample, canine relationship of 31 subjects was not recorded because of extraction or impaction of canines. Analysis was thus carried out on a total sample size of 2369 subjects. General analysis of canine relationship on both sides of occlusion showed canine Class I relationship to be the most prevalent in the sample (right 65.5%, left 59.1%), while canine relationship of all Class II fractions occurred in approximately a third (right 30.7%, left 37.4%), of the sample. In addition, very few of the samples (right 3.9%, left 3.5%) had a Class III canine relationship (Table 4.40).

Crosstabulation of the right and left sides of canine relationship showed that symmetric canine relationship occurred in 81.3% of the sample. Bilateral Class I was found in 53.3% of the sample while bilateral Class II and Class III relationships were found in

25.6% and 2.4% of the sample, respectively. Asymmetrical canine relationship found in 18.7% of the sample were as follows; Class I/Class II in 16.1%, Class I/Class III in 1.9% and Class II/Class III in 0.7% of the sample (Table 4.40).

Table 4.40: Crosstabulation of right and left canine relationship classes

Canine relationship		Left Side						Total	
		Class I		Class II		Class III			
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Right Side	Class I	1263	53.3	270	11.4	18	0.8	*1551*	*65.4*
	Class II	114	4.8	605	25.6	6	0.3	*725*	*30.7*
	Class III	26	1.1	9	0.4	58	2.4	*93*	*3.9*
Total		*1403*	*59.1*	*884*	*37.4*	*82*	*3.5*	*2369*	*100*

Orange Symmetrical (bilateral) molar relationship

Red Asymmetrical molar relationship

Canine relationship of Class II (distal) and Class III (mesial) on right or left sides of occlusion was categorised as discrepancy when there was deviation of at least one-half cusp (½ unit) width distally or mesially to Class I.

Distribution of Class II canine relationship discrepancy was observed mostly in the south (coastal) (right 20.2%, left 18.9%) and east (desert) zones (right 19.9%, left 21.6%). Adolescents living in the north (mountains) zone (right 3.6%, left 2.5%) were found to be more prevalent in Class III canine relationship discrepancy when compared with other zones (Table 4.41). When analysed by gender, more females were observed to have a Class III canine relationship on both sides of the occlusion (right 1.9%, left 2.1%) than males (Table 4.42). The differences of canine relationship discrepancy (Class II and III) by demographic variables were found to be statistically not significant.

Table 4.41: Distribution of canine relationship discrepancy in right and left sides of occlusion by zones

Canine relationship			Zones (N= 2369)										*P*- value[a]
			North (n= 473)		South (n= 471)		Middle (n= 475)		East (n= 473)		West (n= 477)		
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Right side	Class II	Present	79	16.6	95	20.2	74	15.5	92	19.5	73	15.3	0.146
		None	394	83.3	375	79.8	403	84.5	380	80.5	404	84.7	
	Class III	Present	17	3.6	10	2.1	2	0.4	9	1.9	3	0.6	*
		None	456	96.4	460	97.9	475	99.6	463	98.1	474	99.4	
Left side	Class II	Present	94	19.9	89	18.9	76	15.9	102	21.6	75	15.7	0.084
		None	379	80.1	381	81.1	401	84.1	370	78.4	402	84.3	
	Class III	Present	12	2.5	7	1.5	9	1.9	8	1.7	4	0.8	0.360
		None	461	97.5	463	98.5	468	98.1	464	98.3	473	99.2	

[a] Chi-square test conducted, level of significance at $P < 0.05$

*Inferential statistic was not conducted due to very small sample size in each category that will lead to very low power of study

Table 4.42: Distribution of canine relationship discrepancy in right and left sides of occlusion by location and gender

Canine relationship			Location (N= 2369)				*P*- value[a]	Gender (N= 2369)				*P*- value[a]
			Urban (n= 1177)		Rural (n= 1192)			Male (n= 1191)		Female (n= 1178)		
			n	*%*	*n*	*%*		*n*	*%*	*n*	*%*	
Right side	Class II	Present	208	17.7	205	17.2	0.732	222	18.6	191	16.2	0.124
		None	967	82.3	989	82.8		970	81.4	986	82.6	
	Class III	Present	21	1.8	20	1.7	0.834	19	1.6	22	1.9	0.608
		None	1154	98.2	1174	98.3		1173	98.4	1155	98.1	
Left side	Class II	Present	208	17.7	228	19.1	0.382	232	19.5	204	17.3	0.181
		None	967	82.3	966	80.9		960	80.5	973	82.7	
	Class III	Present	23	2.0	17	1.4	0.313	15	1.3	25	2.1	0.102
		None	1152	98.0	1177	98.6		1177	98.7	1152	97.9	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.2.3 Bimaxillary Protrusion

Bimaxillary protrusion was found in 9.3% of the sample. The occurrence was also observed to be more prevalent among the south (coastal) (13.1%) and west (coastal and island) (11.9%) zones adolescents. The middle (plateaus) and north (mountains) zone adolescents had almost half as many with the condition while those living in the east (desert) zone had another one third more (Table 4.43). These inter-zones differences when tested by Chi-square test were found to be highly significant at *P*= 0.000 (Table 4.43).

In addition, female adolescents were observed to have a higher (10.1%) proportion of bimaxillary protrusion than male (8.6%) (Table 4.44). The differences for gender were however statistically not significant.

Table 4.43: Distribution of bimaxillary protrusion by zones

Bi Maxillary protrusion	Zones										Total (N= 2400)		*P*-value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)				
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Present	30	6.3	63	13.1	29	6.0	45	9.4	57	11.9	224	9.3	0.000
None	450	93.7	417	86.9	451	94	435	90.6	423	88.1	2176	90.7	

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.44: Distribution of bimaxillary protrusion by location and gender

Bi Maxillary protrusion	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	%	*n*	%			*n*	%	*n*	%	
Present	111	9.3	113	9.4	0.888		103	8.6	121	10.1	0.207
None	1089	90.7	1087	90.6			1097	91.4	1079	89.9	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.3 Orthodontic Treatment Needs Based on IOTN

Measurements of orthodontic treatment needs included normative assessment for treatment need by clinical examination using the Dental Health Component (DHC) of IOTN. In addition, examiner evaluation and self-perception of subjects on their occlusion were measured by using the Aesthetic Component (AC) of IOTN.

4.3.1 Normative Orthodontic Treatment Need Assessment

A total of 2400 subjects were examined for orthodontic treatment need using the Dental Health Component (DHC) of IOTN. Findings showed that slightly less than half of the total adolescents examined (44.3%) need some form of orthodontic treatment (Grades 3, 4 and 5) (Table 4.45). Of those needing treatment 61.6% was found to be in 'definite' category, while the remaining 38.4% was observed to be in 'borderline' need.

Table 4.45: Distribution of normative orthodontic treatment need as measured by the Dental Health Component (DHC) of IOTN

DHC grades	Grade meaning	Subject number (N= 2400)	Percentage	Treatment needs categories
Grade 5	Very great treatment need	282	11.8	Definite need treatment
Grade 4	Great treatment need	360	15.0	
Grade 3	Borderline treatment need	420	17.5	Borderline need treatment
Grade 2	Little treatment need	574	23.9	No need treatment
Grade 1	No treatment need	764	31.8	

4.3.1.1 Distribution of Normative Orthodontic Treatment Need of the Sample by Demographic Variables

The distribution of normative orthodontic treatment need as measured by the Dental Health Component of IOTN by zones showed that more adolescents from the north (mountains) (31.5%) and east (desert) (30.6%) zones were in 'definite' need category. The least was among adolescents from the west (coastal and island) zone (19.4%). The differences were found to be highly significant at *P*= 0.000 (Table 4.46).

A similar distribution pattern was also observed for those who were categorised in the "borderline" need for orthodontic treatment. The differences were again found to be statistically significant at *P*= 0.036 (Table 4.46).

Table 4.46: Distribution of normative orthodontic treatment need by zones

Treatment needs categories	DHC grades	Zones (N= 2400)										*P*-value[a]
		North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)		
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Definite need	grade 5	57	11.9	69	14.4	62	12.9	49	10.2	45	9.4	0.000
	grade 4	94	19.6	53	11.0	67	14.0	98	20.4	48	10.0	
Borderline need	grade 3	89	17.9	74	15.4	98	20.4	95	19.8	67	14.0	0.036
No need	grade 2	94	19.6	131	27.3	91	19.0	122	25.4	136	28.3	0.000
	grade 1	149	31.0	153	31.9	162	33.8	116	24.2	184	38.3	

[a] Chi-square test conducted, level of significance at $P < 0.05$

The distribution of normative orthodontic treatment need among adolescents by location and gender were as shown in Table 4.47. Slightly more urban (27.6%) than rural (25.9%) adolescents were observed to be in 'definite' need for treatment. The reverse was observed for 'borderline' need. The differences were not statistically significant.

A similar distribution pattern observed for 'definite' need treatment category and gender. Analysis showed more male (19.8%) compared to female adolescents (15.3%) were found to be in 'borderline' need category. The differences was found to be statistically significant at *P*= 0.004.

Table 4.47: Distribution of normative orthodontic treatment need by location (urban & rural) and gender

Treatment needs categories	DHC grades	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
		Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
		n	*%*	*n*	*%*			*n*	*%*	*n*	*%*	
Definite need	grade 5	140	11.7	142	11.8	0.356		142	11.8	140	11.7	0.519
	grade 4	191	15.9	169	14.1			186	15.5	174	14.5	
Borderline need	grade 3	195	16.3	225	18.8	0.107		237	19.8	183	15.3	0.004
No need	grade 2	284	23.7	290	24.2	0.681		258	21.5	316	26.3	0.005
	grade 1	390	32.5	374	31.2			377	31.4	387	32.3	

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.3.2 Orthodontic Treatment Need as Measured by Aesthetic Component of IOTN

Orthodontic treatment needs based on aesthetic perception was evaluated by the Aesthetic Component (AC) of IOTN. The distribution of Aesthetic Component grades as evaluated by the examiner and subjects were as shown in Table 4.48.

Table 4.48: Distribution of Aesthetic Component grades as evaluated by examiner and subjects

Treatment needs categories	AC grades	Examiner assessments		Total (N= 2400)			Subjects assessments		Total (N= 2400)	
		n	%	*n*	%		*n*	%	*n*	%
Definite need	grade 10	22	0.9	244	10.1		21	0.9	113	4.7
	grade 9	46	1.9				37	1.5		
	grade 8	176	7.3				55	2.3		
Borderline need	grade 7	98	4.1	450	18.8		33	1.4	207	8.7
	grade 6	210	8.8				47	2.0		
	grade 5	142	5.9				127	5.3		
No need	grade 4	299	12.5	1706	71.1		247	10.3	2080	86.6
	grade 3	366	15.2				484	20.1		
	grade 2	470	19.6				580	24.2		
	grade 1	571	23.8				769	32.0		

4.3.2.1 Orthodontic Treatment Need as Perceived by Examiner

Orthodontic treatment need (definite or borderline) was perceived by the examiner showed to be slightly more than quarter of the sample (10.1% definite and 18.8%, borderline). Examiner also evaluated 71.1% of the sample as not needing treatment (Table 4.48).

When analysed by zones, a higher proportion (14.4%) of adolescents from the north (mountains) and east (desert) (13.1%) zones were perceived by the examiner to need 'definite' treatment. The examiner also found that the proportion who perceived needing 'borderline' treatment was higher (23.3%) among the middle (plateaus) zone followed by the north (mountains) (19%) and south (coastal) (18.5%) zone adolescents. Distribution of definite and borderline need treatment by zones was shown to be statistically significant at $P < 0.05$ (Table 4.49).

Table 4.49: Distributions of treatment need categories as evaluated by examiner using Aesthetic Component by zones

Treatment needs categories	Zones (N= 2400)										*P*- value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)		
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Definite need	69	14.4	37	7.6	40	8.3	63	13.1	35	7.3	0.000
Borderline need	91	18.9	89	18.6	112	23.3	76	15.8	82	17.1	0.037
No need	320	66.7	354	73.8	328	68.4	341	71.1	363	75.6	0.012

[a] Chi-square test conducted, level of significance at $P < 0.05$

Distribution of aesthetic orthodontic treatment need as perceived by examiner by location (urban & rural) and gender showed a similar distribution pattern in 'definite' need category. However, a higher proportion of male (21.3%) compared to female (16.3%) adolescents were found in 'borderline' need for treatment. The difference was observed to be statistically significant at *P*= 0.002 (Table 4.50).

Table 4.50: Distributions of treatment need categories evaluated by examiner using Aesthetic Component by location (urban & rural) and gender

Treatment needs categories	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	*%*	*n*	*%*			*n*	*%*	*n*	*%*	
Definite need	129	10.8	115	9.6	0.344		134	11.1	110	9.2	0.105
Borderline need	223	18.6	227	18.9	0.834		255	21.3	195	16.3	0.002
No need	848	70.6	858	71.5	0.653		811	67.6	895	74.5	0.000

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.3.2.2 Orthodontic Treatment Need as Perceived by Subjects

Aesthetic orthodontic treatment need as perceived by subjects showed that only a small proportion of the adolescents perceived they need treatment (4.7% definite need and 8.7% borderline need) (Table 4.48).

Most of the 'definite' need was perceived by adolescents living in the north (mountains) (6.9%) and east (desert) (5.6%) while the lowest proportion was in the south (coastal) (2.3%). On the other hand for 'borderline' need, majority of those who perceived they needed treatment lived in the west (coastal and island) (11.9%) and middle (plateaus) (11.1%) zones. The differences were found to be statistically significant at *P*< 0.05

(Table 4.51). More male (6.8%) perceived they need 'definite' treatment compared to females (2.6%). The difference was observed to be statistically significant at *P*= 0.000 (Table 4.52).

Table 4.51: Subject evaluation of treatment need by zones as measured by Aesthetic Component of IOTN

Treatment needs categories	Zones (N= 2400)										*P*- value[a]
	North (n= 480)		South (n= 480)		Middle (n= 480)		East (n= 480)		West (n= 480)		
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Definite need	33	6.9	11	2.3	21	4.4	27	5.6	21	4.4	0.015
Borderline need	43	9.0	35	7.3	53	11.0	19	4.0	57	11.9	0.000
No need	404	84.1	434	90.4	406	84.6	434	90.4	402	83.7	0.001

[a] Chi-square test conducted, level of significance at $P < 0.05$

Table 4.52: Subject evaluation of treatment need by location and gender as measured by Aesthetic Component of IOTN

Treatment needs categories	Location (N= 2400)				*P*-value[a]		Gender (N= 2400)				*P*-value[a]
	Urban (n= 1200)		Rural (n= 1200)				Male (n= 1200)		Female (n= 1200)		
	n	%	*n*	%			*n*	%	*n*	%	
Definite need	58	4.8	55	4.6	0.773		82	6.8	31	2.6	0.000
Borderline need	96	8.0	111	9.3	0.275		115	9.6	92	7.7	0.094
No need	1048	87.2	1034	86.1	0.471		1003	83.6	1077	89.7	0.000

[a] Chi-square test conducted, level of significance at $P < 0.05$

4.4 Relationship of Orthodontic Treatment Need between examiner and Subjects

Crosstabulation between the normative orthodontic treatment need (measured by DHC) and self-perceived treatment need (measured by AC) by subjects was as presented in Table 4.53. Analysis showed slightly more than half (53.5%) were 'true' cases of not needing any orthodontic treatment. However, 'true' cases of 'definite' orthodontic treatment need observed in 3.8% of the sample affected. Results also showed that 33.1% of the adolescents who self-perceived no need treatment were assessed in definite or borderline normative treatment need by DHC.

A weak but significant correlation was found between the orthodontic treatment need categories assessed by examiner (normative orthodontic need) and the subjects perceived ($r = 0.326$, $P = 000$) (Appendix 24).

Table 4.53: Relationship of normative treatment and subjects perceived needs

Treatment needs categories			Normative treatment need (DHC)					Total (%)
			No need (%)		Borderline Need (%)	Definite need (%)		
			grade 1	grade 2	grade 3	grade 4	grade 5	
AC assessment by subjects	No need	grade 1	15.8	8.9	4.2	1.6	1.5	32.0
		grade 2	8.6	6.5	4.4	2.6	2.1	24.2
		grade 3	5.2	4.4	3.6	4.3	2.7	20.1
		grade 4	1.8	2.3	2.6	2.0	1.5	10.3
		subtotal	53.5		14.8	18.3		86.6
	Borderline need	grade 5	0.3	1.2	1.5	1.3	1.0	5.3
		grade 6	0	0.4	0.3	0.8	0.5	2.0
		grade 7	0	0.1	0.2	0.4	0.7	1.4
		subtotal	2.0		2.0	4.7		8.7
	Definite need	grade 8	0.1	0	0.3	1.2	0.7	2.3
		grade 9	0	0	0.2	0.7	0.6	1.5
		grade 10	0	0.1	0.2	0.1	0.5	0.9
		Subtotal	0.2		0.7	3.8		4.7
Total			31.8	23.9	17.5	15	11.8	100

4.5 Malocclusion as Measured by Different Methods

This section of the results showed the prevalence of malocclusion according to the criteria of FDI/WHO basic method for recording occlusal traits and Index of Orthodontic Treatment Need (IOTN). Analysis was conducted separately and then compared.

4.5.1 Prevalence of Malocclusion Based on FDI/WHO Method

The distribution of malocclusion prevalence of Yemeni adolescents based on the FDI/WHO objective method was as shown in Table 4.54. Crowding ≥ 2 mm (27.8%), molar Class II relationship (19.8%), overbite ≥ 2/3 overlap (10.3%), maxillary overjet ≥ 6 mm (9.1%) and impacted teeth (5.7%) ranked as the five highest occlusal traits observed in the sample.

An attempt to determine the total percentage of malocclusion among Yemeni adolescents as measured by the conventional method required analysis of all prevalent occlusal traits of the subjects. As seen in Figure 4.2, findings showed that 74.4% of the Yemeni adolescents were considered to have different severity of malocclusion. While, 25.6% of the sample classified as having normal occlusion.

Table 4.54: Malocclusion prevalence as measured using FDI/WHO method

Malocclusion based on FDI/WHO method	Number of subjects	Percentage
Crowding ≥ 2 mm	669	27.8
Molar Class II relationship	466	19.8
Overbite ≥ 2/3 overlap	236	10.3
Maxillary overjet ≥ 6 mm	209	9.1
Impacted teeth	137	5.7
Maxillary diastema ≥ 2 mm	130	5.4
Posterior crossbite	126	5.2
Anterior openbite	108	4.5
Retained deciduous teeth	76	3.2
Spacing ≥ 2 mm	71	2.9
Posterior openbite	71	2.9
Scissor bite	66	2.7
Missing due to extraction/trauma	66	2.8
Mandibular or reverse overjet	56	2.3
Congenital absent teeth (hypodontia)	52	2.2
Anterior crossbite	47	2.0
Molar Class III relationship	45	1.9
Supernumerary teeth	16	0.7

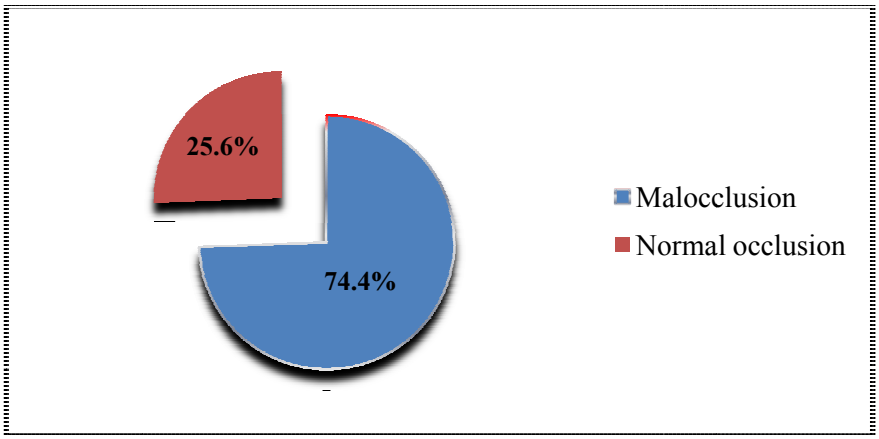


Figure 4.2: Occlusion status based on FDI/WHO method

4.5.2 Prevalence of Malocclusion Based on IOTN

Malocclusion as measured by the Dental Health Component (DHC) of IOTN showed that 68.2% of the sample had some form of discrepancy. The most prevalent discrepancy observed were displacements > 1 mm (25.4%), increased overjet > 3.5 mm (19.7%), impeded eruption (5.7%) and overbite (3.8%) (Table 4.55).

Of those with malocclusion, majority had grade 2 malocclusion (23.9%). The percentage of severity decreased with increasing malocclusion grades with the lowest proportion (11.8%) having grade 5 malocclusion (Table 4.56). Further analysis on the distribution of malocclusion within each grade among demographic variables was as shown in Appendices 21-23.

Table 4.55: Prevalence of malocclusion as measured based on IOTN

Occlusal status by IOTN	Number of subjects	Percentage
Displacements > 1 mm	610	25.4
Increased overjet > 3.5 mm	472	19.7
Impeded eruption	137	5.7
Overbite ≥ 3.5 mm	91	3.8
Openbites > 1 mm	79	3.3
Crossbites > 1 mm and more	65	2.7
Pre-post normal occlusions	30	1.2
Hypodontia	52	2.2
Partially erupted teeth	27	1.1
Reverse overjet > 0	25	1.0
Submerged	17	0.7
Cleft lip and palate	11	0.5
Lingual crossbite	11	0.5
Supernumerary teeth	9	0.4
Total of malocclusion	1636	68.2
Normal occlusion	764	31.8
Total sample	2400	100

Table 4.56: Distribution of different severity of malocclusion responsible in determining grades of treatment need of IOTN

Occlusal traits of DHC grades		Number of subjects	Percentage
5.i	Impeded eruption	137	5.7
5.h	Extensive hypodontia	23	1.0
5.a	Increased overjet > 9 mm	89	3.7
5.m	Reverse overjet > 3.5 mm with speech difficulties	5	0.2
5.p	Cleft lip and palate	11	0.5
5.s	Submerged	17	0.7
Total of Grade 5 malocclusion		**282**	**11.8**
4.h	Less hypodontia	29	1.2
4.a	Increased overjet > 6 mm to ≤ 9 mm	108	4.5
4.b	Reverse overjet > 3.5 mm no speech difficulties	2	0.08
4.m	Reverse overjet > 1 mm < 3.5 mm with speech difficulties	3	0.1
4.c	Crossbites > 2 mm	22	0.9
4.l	Lingual crossbite	11	0.5
4.d	Displacements > 4 mm	141	5.9
4.e	Openbites > 4 mm	8	0.3
4.f	Complete overbite with gingival trauma	0	0
4.t	Partially erupted teeth	27	1.1
4.x	Supernumerary teeth	9	0.4
Total of Grade 4 malocclusion		**360**	**15.0**
3.a	Increased over jet > 3.5 mm to ≤ 6 mm, incompetent	148	6.2
3.b	Reverse overjet > 1 mm to ≤ 3.5 mm	4	0.2
3.c	Crossbites > 1 mm to ≤ 2 mm	25	1.0
3.d	Displacements > 2 mm to ≤ 4 mm	200	8.3
3.e	Openbites > 2 mm to ≤ 4 mm	19	0.8
3.f	Complete overbite no gingival trauma	24	1.0
Total of Grade 3 malocclusion		**420**	**17.5**
2.a	Increased overjet > 3.5 mm to ≤ 6 mm	127	5.3
2.b	Reverse overjet > 0 mm to ≤ 1 mm	11	0.5
2.c	Crossbites ≤ 1 mm	18	0.7
2.d	Displacements > 1 mm to ≤ 2 mm	269	11.2
2.e	Openbites > 1 mm to ≤ 2 mm	52	2.2
2.f	Increased overbite ≥ 3.5 mm no gingival trauma	67	2.8
2.g	Pre-post normal occlusions	30	1.2
Total of Grade 2 malocclusion		**574**	**23.9**
1	Extremely minor malocclusions Grade 1	**764**	**31.8**
Total sample		2400	100.0

4.5.3 Comparison Between Malocclusion as Measured by FDI/WHO Method and DHC of IOTN

Table 4.57 showed the distribution of malocclusion as measured by the two methods. Analysis suggested that the prevalence was higher (74.4%) when measured using the FDI/WHO objective method compared to IOTN measurement (68.2%). The difference observed was 6.2%.

Table 4.57: Occlusion status comparison as measured by FDI/WHO method of occlusal traits and IOTN

Occlusion status	FDI/WHO method		IOTN		Differences	
	n	%	*n*	%	*n*	%
Malocclusion	1785	74.4	1636	68.2	149	6.2
Normal occlusion	615	25.6	764	31.8		

CHAPTER FIVE

DISCUSSION

5.1 General Discussion of the Findings

This study is the first epidemiological study covering the whole geographical areas of Yemen. It deals with malocclusion status and orthodontic treatment need among 14 years old Yemeni adolescents. It is essential to note that the measurement methods of malocclusion and orthodontic treatment need used in this study had been accepted in different populations. Thus findings from this study will allow comparison with findings of other studies.

In general, the higher prevalence of occlusal trait among the sample was observed to be crowding, this being more in the mandible than in the maxilla. On the other hand, spacing was observed to be more prevalent in the maxilla as compared to the mandible. The most prevalent anterio-posterior occlusal relationship was the Class I occlusal relationship followed by that of Class II, and Class III. In addition, results also showed that 88.7% of the sample had symmetrical molar relationship, while only 11.3% had asymmetrical molar relationship indicating presence of the different degrees of occlusal deviation or shifting.

Prevalence of bimaxillary protrusion in the Yemeni sample was higher than in other Middle Eastern findings while being less than in African studies. In addition, most of the bimaxillary protrusion was found in the coastal southern and western zones of Yemen. These comparisons are important as they relate to the historical and geographical location of Yemen being between Middle Eastern and African countries, whereby intermix of the populations may have occurred to have an influence on teeth or jaw development. In the vertical occlusal relationship, females were found to have significantly higher prevalence of openbite than males indicating that the facial height lines are also higher in females than males.

It was also to be noted that the prevalence of malocclusion when using the conventional objective method of FDI/WHO showed a slightly higher prevalence (74.4%) than when measured using the DHC of IOTN (68.2%). Although the difference was only 6.2% it could have an impact not only on the measurement and prevalence of malocclusion but more so on treatment need. The differences in percentage can also have an impact in terms of absolute numbers of occlusal traits when measured by both methods. This becomes critical in a country where the population comprised mostly young of adults.

The Dental Health Component of IOTN had been used in the present study to provide normative orthodontic treatment need. Findings showed that 44.3% of Yemeni adolescents were in 'definite' or 'borderline' need for treatment. Another observation from this study was the Aesthetic Component of IOTN finding whereby only a small percentage of subjects perceived they needed treatment. This may be in part be due to the fact that Yemeni adolescents had not given much attention to their looks, or are not fully aware of their appearance due to other more pressing basic and survival needs.

Nevertheless, it must be recognised that after a long spate of civil war Yemen is emerging slowly as a modern country. As such, there may be an increase in awareness and demand for orthodontic treatment among the younger population in the future. When this happens, there may be an increase in perceived need for treatment which means more orthodontists are required in the country.

5.2 Occlusal Traits Based on FDI/WHO Method

5.2.1 Dental Discrepancies

5.2.1.1 Missing Permanent Teeth

Among the Yemeni adolescents examined, 5.7% of the sample had impacted teeth. The observed finding was lower than when compared to that previously reported in Middle Eastern studies. Al-Emran et al. (1990) found 10.4% impacted teeth among 14 years-old Saudi Arabian males. Hamadan (2001) in his study among 320 Jordanian school children aged 14-17 year-old had showed 24% of the children had impacted teeth. In another study, Abu Alhaija et al. (2004) who examined 1002 North Jordanians aged 12-14 year-old found 17% had impacted teeth. The small sample size in these studies might have contributed to the difference in the prevalence of impacted teeth reported.

However, the finding of impacted teeth in the current study was higher than those found by Thilander et al. (2001) who reported a 3.1% prevalence of impacted teeth in Colombia. There is a possible explanation for this inconsistency in the results; it might be explained by cultural beliefs and practise in the different ethnic groups which might be the reason for early loss of primary teeth, an important etiological factor for tooth impaction. In Yemen, due to lack of systematic caries treatment and poor oral hygiene habits, early extraction of primary teeth was a common practice causing loss of space for the permanent successors (Al-Haddad et al., 2009). There are similarities however, between the finding of this study and those described by Al-Emran et al. (1990) who found impacted teeth more frequently involving the mandibular second premolar and maxillary canine.

Another point of interest was the observation of no oligodontia or anodontia. In addition, only 2.2% of the sample had hypodontia. In reviewing the literature, hypodontia (excluding third molar) was noted to be a relatively common feature in

many different population groups ranging from 2% to 11.3% (Thilander and Myrberg, 1973; Al-Emran et al., 1990; Thilander et al., 2001; Hamdan, 2001; Fekonja, 2005). The prevalence of hypodontia among Yemeni adolescents was found to be within the above range. A good agreement was observed between the present finding and 2% hypodontia in Jordanian population as reported by Hamdan (2001).

Hypodontia reported in this study exhibited a lower proportion when compared with other studies that found 4 to 11% of their samples with the condition (Fekonja, 2005; Chung et al., 2008). A possible explanation for that low prevalence of hypodontia among the Yemeni sample might be due to hereditary factor differences, the most important aetiological factors in congenital absence of teeth. Another plausible explanation is the fact that this study did not involve radiographic examination, thus causing an underestimation to be made. The most frequently congenitally absent teeth in Yemeni adolescents were found to be the maxillary lateral incisors, followed by mandibular second premolar and mandibular incisors. This finding was similar with the Slovenian figure reported by Fekonja (2005) and Brazilian study sample (Gomes et al., 2010).

Finding of the present study showed 2.8% of the sample had missing teeth due to extraction or trauma, with the most commonly extracted tooth to be the mandibular first molar. The finding was similar to other previous studies by (Massler and Frankel, 1951; Mũniz, 1986). Mandibular molar was the first permanent teeth to erupt in the mouth and had been established to be highly susceptible to caries, especially when poor oral hygiene was present (Leroy et al., 2005).

5.2.1.2 Supernumerary and Retained Deciduous Teeth

In this study sample, 0.7% had supernumerary teeth. This finding was comparable to that found by Vahid-Dastjerdi et al. (2011) who reported a 0.74% prevalence of supernumerary teeth among Iranian study sample. Finding from this study however, showed lower than that found by Thilander et al. (2001) who reported a prevalence of 1.8%, and Ezoddini et al. (2007) who found 3.5% of their study sample had supernumerary teeth. These differences between Yemeni and other studies could in part be attributed to ethnic group differences which could influence the development of dentition.

The most common supernumerary teeth in Yemeni adolescents were the maxillary incisors. This finding agreed with an earlier orthodontic research that showed 90% of all supernumerary teeth observed in the anterior part of the maxilla (Primosch, 1981).

Retained deciduous teeth were observed in 2.8% of the subjects in this study. This finding concurred with that reported by Cons et al. (1978) who observed 3.2% of 15-18 year-old sample had one or more retained deciduous teeth. The most frequently retained deciduous teeth in the Yemeni sample were found to be the second molars and maxillary canines. A possible reason of these retained deciduous teeth might be related to high prevalence of impacted teeth of second premolars and maxillary canine found in this study. Impacted permanent teeth had been established to be one of main cause retained deciduous teeth (Aktan et al., 2011).

5.2.2 Space Discrepancies

5.2.2.1 Crowding and Spacing

Crowding was found to be the most common occlusal trait in this study, whereby 53.3% of the sample had varying crowding severity in one or both jaws. The prevalence of crowding reported was comparable to findings of Proffit et al. (1998) among 12-17 year-old subjects in the United States (54.5%). Krzypow et al. (1975) in their study showed crowding in an Israeli sample of different ethnic groups (including of Yemeni origin) to be 50.5%. Similarly, Abu Alhaija et al. (2005a) found the prevalence of crowding in the Jordanian population to be 50.4%. These findings could be expected given the ethnic Yemeni had genetic relationship with the Caucasian population.

On the other hand, findings of crowding in the current study were higher than that from the African malocclusion studies. Isiekwe (1983) reported a 15% crowding in 10 to 19 years old Nigerians. In another Nigerian study conducted by Onyeaso (2004), crowding was found in 20.1% of the sample. Similarly, the prevalence of crowding in Tanzania was also found to be lower than our findings. Mugonzibwa et al. (2008) studied children from Dar es Salam and found 9% crowding in the permanent teeth stage. Recently, a study by Mtaya et al. (2009) who examined 1601 Tanzanian adolescents reported that 14.1% of the subjects had crowding. These differences in prevalence of crowding between our study and the African studies could be explained in terms of genetic factors influencing variation in space anomalies among different ethnic groups. However, this concurs with many studies in permanent dentition which reported a higher prevalence of crowding in Caucasian as compared to African children (Lavelle, 1976; Kerosuo et al., 1991; Mugonzibwa et al., 2008).

Studies by various authors have shown that the prevalence of spacing varied from country to country and among races. A wide variation was reported ranging from 8% in Croatian (Lauc, 2003) to 23.6% in Tanzanian samples (Mugonzibwa et al., 2008). The current study finding of 12% prevalence of varying spacing severity (in one or both jaws) was in agreement with that of Ingervall et al. (1978) (13%) and Salonen et al. (1992) (10.2%). On the contrary, findings in the present study did not concur with that of Gardiner (1982) who found a 20.3% prevalence of spacing in 10-12 years old Libyans. This contradictory finding might be due to the difference in age groups and could be explained by the fact that at 10-12 years old they would have normal anterior spacing (ugly duckling stage), while by age 13-14 years the canines would have erupted and closed the anterior spaces.

In the present study, prevalence of ≥ 2mm spacing in the maxilla was 2.3% which was more than in the mandible (0.8%). Crowding of ≥ 2mm was found more frequently in the mandible (25.1%) than in maxilla (9.2%). This figure of present space discrepancies were in agreement with that reported among 15 to 20 year-old British (Lavelle, 1976), Swedish (Mohlin, 1982), Saudi Arabian adolescents (Al-Emran et al., 1990), and Caucasian sample of Mugonzibwa et al., (2008). On the other hand, space discrepancies found in this study were not similar to Lux et al. (2008) study, who found crowding to be more often in the maxilla than in the mandible. Similarly, Mtaya et al. (2009) observed both crowding and spacing to be more often in the maxilla than mandibular arch. The differences in these space discrepancies figures could be explained in terms of environmental factors and craniofacial growth among different ethnic groups. A review of the literature had suggested that environmental factors could be a more important influence especially with reference to crowding (Harris and Johnson, 1991).

Comparing by geographical zones, the present study showed statistically significant differences between the five zones with regards to distribution of ≥ 2 mm crowding in both jaws and ≥ 2 mm spacing in the maxilla. A high prevalence of crowding in both jaws was found in the east (desert) and north (mountains) zones, while prevalence of spacing were found to be higher among adolescents living in south and west zones (coastal). Incidentally these differences between zones are the first to be reported and might be due to variations in climate and living style of the different zones. These factors might have an influence on the growth and development of the maxilla and mandible.

This study also showed no significant differences between males and females concerning crowding and spacing, which were in agreement with those of other studies (Onyeaso, 2004; Behbehani et al., 2005). For many years, most parts of Yemen were an isolated country except for coastal areas. However, with modernisation and change in lifestyle malocclusion may pose a different picture. A follow-up study may need to be done in future to see if any differences occur. In the meantime these findings can be considered as baseline information.

5.2.2.2 Maxillary Midline Diastema

The 5.4% prevalence of maxillary midline diastema ≥2 mm found was comparable with 4% from other studies (Al-Emran et al., 1990; Thilander et al., 2001). Other Middle East studies had also reported slightly higher rates of maxillary diastema. Behbehani et al. (2005) reported that 6.9% of Kuwaiti sample had diastema without other spacing. Similarly Gelgör et al. (2007) found 7% of their Turkish study subjects had maxillary diastema. This difference in the results may be explained by the fact that this study

measured maxillary diastema as being 2 mm and more, while the Kuwaiti and Turkish studies used measurement of ≥ 0.5 mm and ≥ 1 mm, respectively.

It is interesting to note that in the African population diastema was regarded as a mark of natural beauty (Onyeaso, 2004), while in Middle East studies it was regarded as malocclusion (Al-Emran et al. 1990). Moreover, diastema was reported to have a higher prevalence in African compared to Caucasian studies. Onyeaso, (2004) reported that 36.8% of 14 year-old Nigerian sample had diastema. Ajayi (2008) in another Nigerian study on 441 school children in Benin City found 19.5% had maxillary diastema. Given the above differences, diastema as an important malocclusion feature among Middle Eastern population perhaps should be highlighted when measuring for malocclusion.

On the Yemen home front, issues emerging from findings related to geographical zones showed that the north (mountains) and middle (plateaus) zones had significantly more adolescents with diastema than their other peers, while the south (coastal) zone had the least prevalence of diastema. The reason for this is not clear but might be related to different dimensions of the maxillary arches which again could be related to diet and environmental factors. Concerning gender differences with regard to maxillary diastema, no significant differences were found between males and females. There were similarities between the attitudes expressed by the different gender in the current study and those described by Gelgör, (2007) and Behbehani et al. (2005).

5.2.3 Occlusal Discrepancies

5.2.3.1 Occlusal Discrepancies in Antero-posterior Relationship

5.2.3.1.1 Molar Relationship

Molar relationship is considered as important clinical information in the assessment of buccal segment. Many orthodontists diagnosed orthodontic cases according to anterio-posterior occlusal relationship based on first molar relationship (Angle Classification). Overall findings in this study appeared to suggest that symmetrical Class I molar relationships were the most common occurrence (58.7%) followed by Class II and Class III, respectively. This concurred with other studies (Abu Alhaija et al., 2005a and Jonsson et al., 2007). Behbehani et al. (2005) assessed, 1299 13-year-old Kuwaiti children and reported that 57.8% of them had Class I molar relationship. Strikingly different findings however, were found in African studies which showed considerably higher percentage of Class I molar relationship. Kerosuo et al. (1988) in their study reported a prevalence of 96% in a sample of 642 urban Tanzanians, while Garner and Butt (1985) found 69% of the condition in their Kenyan sample. These inconsistencies might be due to racial differences.

With regards to symmetrical Class II molar relationship, the 27.3% prevalence found in this study was consistent to the findings of 28% in an Israel sample of various ethnic backgrounds including 22 Yemenis (Krzypow et al., 1975). In addition, Jonsson et al. (2007) reported 27.7% distal molar occlusion was observed among Iceland adults. However, findings in the present study were closer to that of Behbehani et al. (2005) who reported a prevalence of 31% Class II molar relationship in their Kuwaiti sample.

The proportion of Class II molar relationship in the current study however showed a lower prevalence than the 45.1% by Lauc (2003) in a Croatian study and 44.7% by Gelgör et al. (2007) in their study in Turkey. Nonetheless, our findings exhibited a

higher prevalence of Class II molar relationship when compared with American black population study (Garner and Butt, 1985) and African studies (Isiekwe, 1983; Onyeaso, 2004). Other studies that reported a lower prevalence of Class II malocclusion were 8% and 3% among Kenyan and Tanzanian urban samples, respectively (Garner and Butt, 1985; Kerosuo et al., 1988). These differences between our findings and the Africans figures were somewhat similar to differences found between Caucasians and Negroid population in terms of Class II malocclusion (Horowitz, 1970; Trottman and Elsbach, 1996).

Prevalence of Class III malocclusion also appeared to have wide variations amongst various races. Caucasian studies among the Israeli and the Saudi Arabian children reported a 3% Class III malocclusion (Krzypow et al., 1975; Al-Emran et al., 1990), also the Italian schoolchildren study found a 4.3% of the sample with Class III (Perillo et al., 2010). These Caucasian findings showed close to the present study results of Class III molar relationship (2.7%).

It was also found that Class II molar relationship in Yemeni adolescents was approximately nine times as common as the Class III molar relationship. This figure is similar to the findings reported by Lauc (2003) and Krzypow et al. (1975), which showed the same proportion between Class II and Class III relationships.

Asymmetrical molar relationship was found in 11% of the Yemeni sample. A possible explanation for the differences between right and left sides is that it might be due to the asymmetrical premature loss of deciduous molars, the cause of mesial migration of the first permanent molars.

The present study also showed that more adolescents in the coastal (south) and desert (east) areas had Class II ½ unit or more molar relationship. On the other hand, more of

those with Class III ½ unit or more molar relationship were observed to be with adolescents living in the mountain (north) zone. These inconsistencies between the zones were statistically significant and the differences observed had not been previously reported.

Similar to previous findings (Thilander et al., 2001; Gelgör et al., 2007), it was found that there were more females with Class III molar relationship compared to males. This difference might be due to genetic factors, as had been suggested by Cruz et al. (2008). No difference was observed in the prevalence of molar relationship between urban and rural areas. This could be in part attributed to the little change in culture and lifestyle of today's youths throughout Yemen. This might however change in the future as Yemen moved progressively forward to become a modern country.

5.2.3.1.2 Overjet

The majority of the sample had an acceptable overjet, which is in agreement with other studies (Lauc, 2003; Tausche et al., 2004; Souames et al., 2006; Jonsson et al., 2007). With respect to the 9.1% of sample having increased maxillary overjet of ≥ 6 mm; this value is very close to the finding in a Kuwaiti Arab sample by Behbehani et al. (2005) who reported that 7.8% of the sample had overjet greater than 6 mm. In addition, it is not far from the finding of Jonsson et al. (2007), who showed a prevalence of 10.6% in Icelandic adults overjet ≥ 6 mm.

With regards to increased overjet, this study showed a strikingly lower prevalence when compared with results of other studies on Middle East populations. Al-Emran et al. (1990) showed that 18.4% of 14 year-old Saudi Arabian school children had increased overjet, while Gelgör et al. (2007) found a higher prevalence (25.1%) in 12-17 year-old Turkish sample. The differences in results might be explained by the variation in

categorising normal and increased overjet. Al-Emran et al. (1990) considered increased overjet when overjet was greater than 5 mm, but the Turkish study classified overjet of more than 3 mm to be in that category. In another study, Hamadan (2001) reported 22% prevalence of overjet was greater than 6 mm in 14-17 year-old adolescents. However, this Jordanian study had a much smaller sample size (n=320) compared to this study (n=2400).

The present study did not show statistically significant differences in the prevalence of increased overjet between demographic variables (topographical zones, urban-rural and gender). Yemeni males had a higher proportion of increased overjet than females. This finding was similar to the figure reported by Brunelle et al. (1996).

Mandibular or reverse overjet was found in 2.3% of the Yemeni sample. This finding was close to that reported in other studies (Al-Emran et al. 1990; Bahbehani et al. 2005; Borzabadi-Farahani et al. 2009). Al-Emran et al. (1990) observed a reverse overjet in 3.2% of Saudi Arabia 14-year-old while Bahbehani et al. (2005) reported 4% a reverse overjet in Kuwaiti adolescents. In addition, Borzabadi-Farahani et al. (2009) found a 4.2% occurrence of reverse overjet among 11-14 year-old Iranian children. However, finding on reverse overjet in the present study was less than in the Chinese study by Tang (1994) who reported a prevalence of 15.4%. These differences indicated that Mongoloid's face such as in the Chinese has a tendency to have a retrognathic profile, more than the Caucasian's face.

The association of reverse overjet between topographical zones, location, and gender was found to be statistically not significant. Females were observed to have a slightly higher prevalence of reverse overjet than males. This could be explained by the fact that there were more females than males in Class III molar relationship. This finding was similar to the Turkish finding (Gelgör et al., 2007) that showed more females (130) than males (113) having reverse overjet.

5.2.3.1.3 Anterior Crossbite

The prevalence of anterior crossbite in the present study was 2% of the sample, of whom 1.1% had one inverted incisor while 0.9% had two or three inverted incisors. The present findings were comparable to the results of Diagne et al. (1993) who reported 1.6% anterior crossbite in 1708 school children, however they are smaller than that reported by Můniz (1986) (3.2% anterior crossbite in Amerindian) or the 3.8% prevalence found in the children of Saudi Arabia (Al-Emran et al., 1990).

The prevalence of anterior crossbite in Yemeni adolescents was also much lower than that reported by Krzypow et al. (1975) for the Israeli population (6.3%), Behbehani et al. (2005) for Kuwaitis adolescents (20.8%), and Borzabadi-Farahani et al. (2009) for 11-14 year-old Iranian (8.4%). The higher prevalence observed in these other studies might be due to the fact that there were more crowding observed in the Israel children (50.5%), a high prevalence of irregularity in maxillary anterior segment among Kuwaiti children (70%), and also more crowding observed in the maxilla of Iranian children (75.2%) when compared to this study. The high prevalence of crowding might be responsible for the increase in probability of irregular eruption of the incisors.

The majority of inverted incisors were of a single tooth as found in this study. They are similar with that reported in the Kuwait study by Behbehani et al. (2005). It is of interest to note that the commonly affected inverted tooth was observed in the maxillary lateral incisors. This finding agrees with other reports (Helm, 1968; Al-Emran et al. 1990; Behbehani et al. 2005). The more frequent inverted maxillary lateral incisors observed might be due to the more frequent palatal position of the maxillary lateral incisors during the developmental stage.

5.2.3.2 Occlusal Discrepancies in Vertical Relationship

5.2.3.2.1 Overbite

As mentioned in the literature review, the definition and measurement of normal and deepbite varied considerably making comparisons difficult (Brunelle et al., 1996). There were studies that recorded overbite by millimetre (Cons et al., 1978; Al-Emran et al., 1990, Brunelle et al., 1996), while other studies measured overbite according to different indices by millimetre and represented the results not by means of overbite but by grades, categorising them into mild, moderate, and severe overbite (Lauc, 2003; Thilander et al., 2001; Hamadan, 2001; Abdullah and Rock, 2001). In addition, several occlusal assessment studies recorded overbite by fractions of overlap of the incisors namely; 1/3, 2/3 and more than 2/3 (Mũniz, 1986; Diagne et al., 1993; Tang, 1994; Onyeaso, 2004; Behbehani et al., 2005; Gelgör et al., 2007; Borzabadi-Farahani et al., 2009).

The present study found that deep overbite of the middle third overlap or more (10.3%) was approximately twice as frequent as the anterior openbite (4.5%). This finding was similar to other studies on malocclusion (Tang, 1994; Thilander et al., 2001; Onyeaso, 2004; Gelgör et al., 2007). The prevalence of deepbite reported in this study is comparable with results from Mũniz (1986) who reported 11.6% prevalence among Caucasian children had an overbite of ≥ two-thirds overlap, and Jonsson et al. (2007) who found 11.8% deep overbite in Icelandic adult populations.

Results of the present study appeared to be higher than those of Al-Emran et al. (1990) who found 3.6% of the Saudi Arabian sample had deep overbite. This difference might be due to the different measurement methods used to measure deep overbite. The Saudi Arabian study recorded deepbite in instances where the overbite more than 5 mm but our study measured deep bite as that of ≥ two-thirds overlap. The findings of this study

also found to be higher than that reported in African study sample. Diagne et al. (1993) found that 4.7% of the Senegalese sample had deepbite, while Mtaya et al. (2009) observed 0.9% Tanzanian with deepbite ≥ 5 mm. A possible explanation for these differences might be due to the high prevalence of bimaxillary protrusion seen in the African studies, which was characterised by a decrease in the inter-incisal angle leading to reduced overbite.

In the present study, more adolescents with deep overbite were those living in the middle (plateaus) and west (coastal and island) zones, while only a small proportion of the east (desert) and north (mountains) zones adolescents were affected. As mentioned earlier, this statistically significant difference between zones might be due to variations in diet and climate.

5.2.3.2.2 Anterior Openbite

Previous findings on the prevalence of anterior openbite in the literature were varied. Lavelle et al. (1976) found 8.4% of British subjects with anterior openbite. In other studies, Jonsson et al. (2007) reported that 2.5% of 829 Icelandic study samples had anterior openbite while, Ingervall et al. (1978) observed 3.7% prevalence in Swedish adults. Lauc (2003) reported anterior openbite on 3.1% of Croatian sample. The 4.5% anterior openbite observed in Yemeni adolescents was similar to that of the Caucasian studies.

In general, there were statistically significant differences in the distribution of anterior openbite between the five geographical territories of Yemen. East (desert) and west (coastal and island) zones had more anterior openbite while the south (coastal) zone had the lowest prevalence. Although habits such as digit sucking are known to play a role in

the development of anterior openbite, the discrepancy observed might also be due to genetic factors.

Findings in the present study showed that anterior openbite was significantly more among females than males, comparable to a study conducted by Cons et al. (1978) who reported that digit sucking was more prevalent among females.

5.2.3.2.3 Posterior Openbite

The present study found posterior openbite to be less commonly observed in Yemeni adolescents (2.9%). This concurred with Ingervall et al. (1978) who found a prevalence of 2.2% in a Swedish study sample. Gábris et al. (2006) reported 2% prevalence among 16-18 year-old Hungarian adolescents. In contrast to the present study, lower prevalence figures were reported by a British study (0.4%) (Lavelle, 1976), Saudi Arabian (0.6%) study by Al-Emran et al. (1990), and Tanzanian study (1.1%) by Mtaya et al. (2009). The dissimilarity might be attributed to the smaller sample sizes in these three studies.

Statistically significant differences between genders were also found among Yemeni subjects with posterior openbite. Female had a higher prevalence than male. These patterns of posterior openbite suggest the possibility of female having higher facial height than in male profiles in the vertical occlusal relationship.

5.2.3.3 Occlusal Discrepancies in Transversal Relationship

5.2.3.3.1 Posterior Crossbite

Posterior crossbite was recorded in 5.2% of Yemeni adolescent (3.7% unilateral and 1.5% bilateral). Our findings agreed with those reported by Thilander et al. (2001) in a Colombian sample (4.6%) and among Tanzanian adolescents (5.1%) (Mtaya et al., 2009).

The prevalence of posterior crossbite in this study was also lower than those reported by Krzypow et al. (1975) (11%), Jonsson et al. (2007) (24.6%), Gelgör et al. (2007) (9.5%) and Perillo et al. (2010) (14.2%). This low percentage of posterior crossbite might be a reflection of the low prevalence of molar Class III malocclusion among Yemeni adolescents compared to these studies. This finding supported the suggestion that due to the prognathic position of the mandible, posterior crossbite was often observed in Angle Class III cases.

The present study also showed that there were more unilateral posterior crossbite than bilateral crossbite in Yemeni adolescents. Unilateral posterior crossbite was more frequently found on the right side (2.4%) than on the left side (1.3%). These findings were similar to the findings of Al-Emran et al. (1990), Thilander et al. (2001), Lauc (2003), Gelgör et al. (2007), and Borzabadi-Farahani et al. (2009).

In relation to the transversal occlusal discrepancies, posterior crossbite was twice as frequent as scissor bite. Our results concurred with findings of Al-Emran et al. (1990) and Ng'ang'a et al. (1996) was that posterior crossbite the common occlusal discrepancy in transversal relationship.

5.2.3.3.2 Scissor bite

The prevalence of scissor bite observed in this study was 2.7% of the sample. This prevalence of scissor bite is in agreement with previous reports of 3%, 3.2% and 2% by Ingervall et al. (1978), Al-Emran et al. (1990) and Borzabadi-Farahani et al. (2009), respectively.

However, when compared with the Senegalese study finding of 1% scissor bite by Diagne et al. (1993), current study finding reported slightly higher. This may be due to subjects being of different racial groups, and the fact that scissor bite occurs mostly in Class II division 1 malocclusion. The prevalence of Class II malocclusion in this study was more than the 12.7% recorded by Diagne et al. (1993).

Almost equal distribution of scissor bite on right and left sides was found. This concurred with previous findings among Saudi Arabia adolescents (Al-Emran et al., 1990), a Croatian sample (Lauc, 2003), and Turkish school children (Gelgör et al., 2007).

5.3 Additional Occlusal Traits Observed

5.3.1 Partially Erupted Teeth

In the present study, 6.5% of the sample had partially erupted teeth. This finding is slightly higher than the 4% found by Abdullah and Rock (2001) in their 12-13 year-old Malaysian sample, and the 4.7% of the 14-16 years Iranian sample (Safavi et al., 2009). The varying prevalence could in part be attributed to the different ways of collecting the information, despite both Malaysian and Iranian studies recorded this aspect based on hierarchy of the Index of Orthodontic Treatment Need.

The most common partially erupted teeth in Yemeni adolescents were maxillary canine, mandibular canine and mandibular second premolar. To the knowledge of the author, there was no previous specific study was done on partially erupted teeth in order to allow its comparison. The possible explanation for the more frequently partially erupted teeth in canines and mandibular second premolar might be because these teeth erupted later than their neighbouring teeth.

The differences in the prevalence of partially erupted teeth between geographical zones were found to be statistically significant. The highest prevalence of partially erupted teeth was observed in the north zone (mountains) and the smallest proportion was in the west zone (coastal and island). The reason for these differences was not clear but it may be related to prevalence of crowding. In this study partially erupted teeth are observed more in cases of crowding. Coincidentally, prevalence of crowding was higher in the north (mountains), while lower percentage in the west (coastal and island) zones.

5.3.2 Canine Relationship

Molar relationship which is considered to be of clinical importance in diagnosing buccal segment does not always match the canine relationship. Information on canine relationship provides relevant information on the severity of malocclusion. In addition, orthodontists usually focus on canine relationship at the end of orthodontic treatment.

Symmetrical Class I canine relationship was found in 53% of this study sample. This finding was higher than that reported by Behbehani at al. (2005) on the Kuwaiti sample (36%). The difference might be due to the high prevalence (70%) of malalignment in the anterior segments for both arches in the Kuwaiti sample. In addition, the much higher crowding might have influenced the canine position.

The rate of occurrence of symmetrical Class II canine relationship (25.6%) found in this study was almost equal to the finding of sagittal relationship malocclusion as measured by Angle Classification among subjects of various ethnic backgrounds in Israel (28%) as reported by (Krzypow et al., 1975).

The prevalence of Class III malocclusion in this study (2.4%) is very close to that found by Al-Emran et al. (1990) who reported 3% prevalence among 14 year-old Saudi Arabian sample with Class III relationship.

Results of the present study showed that the differences of canine relationship discrepancy among demographic variables were statistically not significant.

5.3.3 Bimaxillary Protrusion

Although Thilander et al. (2001) stated that bimaxillary protrusion was not difficult to be determined clinically by orthodontists, it was however more difficult to assess severity of bimaxillary protrusion (mild, moderate, and sever) cases without lateral cephalometric radiography. In this study, no radiograph examination was done thus limiting interpretation of the findings.

The prevalence of bimaxillary protrusion in this study was found to be 9.3%, considerably lower than that reported by Isiekwe (1990) for his Nigerian sample (20%). The difference might be due to the varying anterio-posterior relationship of occlusion growth patterns between races. Thilander et al. (2001) in their study also stated that bimaxillary protrusion features were highly prevalent in black populations.

The results of this study did not also concur with those of Middle East study by Hussein and Abu Mois (2007) who reported Palestinian adults features to be similar to Caucasians and did not have distinct features of bimaxillary protrusion.

Prevalence of bimaxillary protrusion among Yemeni adolescents in this study was lower than in the African study but higher when compared with Middle Eastern study. This might be due to location and historical background of Yemen, being located in the south-west corner of the Arabic peninsula closest to Africa, with history of trade ties with Africa. In addition, Yemen was colonised by Ethiopia thousands of years ago. It is therefore not surprising if there is any interchange of culture, eating habits as well as genetically-determine influence in skull growth.

Bimaxillary protrusion was found mostly among south and west zones adolescents. Low prevalence however was found in middle and north zones. The southern (coastal) and western (coastal and island) zones of Yemen had a long standing interaction of races since the early days due to sea trading. On the other hand, the zones with low prevalence of bimaxillary protrusion were more secluded with isolated lifestyle since the early days and comprised mainly of mountains and plateaus.

5.4 Orthodontic Treatment Needs as Measured by IOTN

5.4.1 Normative Orthodontic Treatment Need Assessment

Yemen has 25 orthodontists to serve the 20 million population (Appendix 26). However to date, there is no information on the actual need for orthodontic treatment. Such information is important and relevant for planning future dental services as well as for projection of manpower needed to provide the service.

In this study, the Index of Orthodontic Treatment Need was used to allow comparison to be made with similar studies globally. In addition, the Index had been established to be reliable and used in the Middle East countries (Hassan, 2006). It comprised of two parts, the Dental Health Component that measure normative needs for orthodontic treatment and the Aesthetic Component which compared the need for treatment as measured by the operator or perceived by the subjects.

Findings from this study showed the proportion of 14 year-old adolescents needing 'definite' orthodontic treatment (26.8%) to be comparable with several studies involving Caucasian children as reported by Birkeland et al. 1996 (26.1%), Hamdan, 2001 (27.5%), Tausche et al. 2004 (26.2%) and Perillo et al. 2010 (27.3%). Findings from this study however, showed slightly lower rates than that reported by Bernabé and Flores-Mir (2006a) in 18-year-old Peruvian university students (29.9%) and several British studies by Brooke and Shaw (1989) (32.7%), Holmes (1992) (32%) and Burden (1995) (36%).

Our findings were however higher than some other Caucasian studies (Souames et al., 2006; Manzanera et al., 2009; Danaei and Salehi, 2010) who observed a 21%, 17.1% and 12% 'definite' treatment need for French, Spanish and Iranian children, respectively. Our finding was also higher than that reported in African countries by Otuyemi et al. (1997) (12.6%), Mugonzibwa et al. (20040 (22%) and Ajayi (2008)

(19.2%). Apart from ethnic and environmental differences, the smaller sample size of these studies relative to the present study might be reasons for the observed differences between their findings and the present study.

Compared to Asian studies, this study showed a much lower prevalence. Esa and Razak (1998) found 37.4% of 12 year old Malaysian children in Klang needed treatment for their malocclusion. Baharon (1999) reported 47.2% of the 16-year old in one district in Johor needed treatment. A similar observation on a national scale (46.9%) was observed among Malaysian 12-13 year-olds by Abdullah and Rock (2001). In another study involving 700 Nepalese children, Sharma (2009) observed a 62% 'definite' need for treatment. The observed difference between Yemeni and other Asian children could in part be attributed to culture, environmental and ethnic group differences which could influence the development of occlusion. Malaysian and Nepalese children generally have Mongoloid features. On the other hand Yemeni children have Caucasian features.

Despite living in one country, it was of interest to note that statistical differences of need for treatment were observed amongst Yemeni children living in different geographical zones. These differences in part could be attributed to both geographical and external factors influencing their jaw and teeth development. For example, the observed low proportion needing treatment amongst adolescents living in the two coastal zones (south and west) could be attributed to their diet which was richer in minerals necessary for the development of the teeth and bones. In addition, populations from these two zones had more contact with the outside Western, Asian and African countries through marine trading. Such contact could contribute to the relatively more modern lifestyle and higher literacy rates as well as a more open global outlook. On the other hand, the northern and eastern zones populations which reported the highest need for treatment had a more introvert and for many years had lived in a closed society. In

addition they were surrounded by rough terrains and had a diet that may not be balanced.

This study also reported no differences in treatment needs (definite or borderline) when comparing by rural-urban setting. For many years Yemen had been engaged in civil wars, its people very protective of their culture, thus allowing very little influence on their traditional lifestyle. In addition, the political influence of communism isolated the country and gave little leeway for economic development. These might be among the reasons why no difference was seen between subjects with these levels of treatment needs in urban and rural areas. However, the picture might be different in the future, given that Yemen had decided to open its doors to the outside world as it moved towards economic and infrastructure development and modernisation.

The distribution of orthodontic treatment need by gender had been reported by several studies. Mandall et al. (1999) reported more treatment need among females than males. On the other hand Burden et al. (1994) and Hedayati et al. (2007) reported otherwise in their studies involving 14-15 year-old Manchester and, 11-14 year-old Iranian schoolchildren, respectively. Interestingly, both Norwegian (Birkeland et al., 1996) and Turkish (Üçüncü and Ertugay, 2001) studies reported no gender difference. No difference between gender in terms of treatment need was also observed in this study. This was to be expected as both groups were exposed to the same living conditions with little exposure to more developed countries.

5.4.2 Orthodontic Treatment Need as Measured by the Aesthetic Component (AC) of IOTN

Aesthetic Component of the Index of Orthodontic Treatment Need (AC-IOTN) was developed using intraoral photographs of dentition with different occlusal discrepancies. The need for this assessment was based on the rationale that individual's perception on their dental appearance could have considerable importance and influence on both treatment demand and patient's compliance and cooperation during treatment (Shaw, 1981).

In using this measurement, many studies had highlighted on the importance of subject's age which could have an influence on the way subjects perceived their aesthetic and well being (Burden and Holmes, 1994; Pietilá and Pietilá, 1996; Kolawole et al., 2008). Holmes (1992) was of the opinion that younger children were less aware of their aesthetics and thus providing judgement and making decisions on their malocclusion can be a difficult task for them. For these reasons thus, the present study chose adolescents who were considered to be more aware of their dental appearance and capable of expressing their opinions.

5.4.2.1 Aesthetic Component (AC) Assessment by Examiner

'Definite' need for treatment as assessed by the examiner using the AC measurement was found in only a tenth (10.1%) of the adolescents. The finding concurred with that of Burden and Holmes (1994) who assessed 955 first-year secondary children in Sheffield, England and reported an 8.5% need. In a similar study, Mandall et al. (1999) assessed 14-15-year-olds Manchester schoolchildren and observed a 9% 'definite' need for treatment. Our study finding is also comparable to another study by Dias and Gleiser (2010) who found 11% of their Brazilian schoolchildren needed treatment to improve their aesthetics.

While no gender differences were observed, findings from this study showed statistical differences between need for treatment as assessed by geographical zones. Adolescents living in the mountainous (north) and desert (east) of Yemen showed less aesthetic concerns as compared to the relatively more 'exposed' parts of Yemen. As mention previously, this was probably due to the isolated traditional lifestyle of the northern and eastern parts of Yemen as compared to the more progressive areas. But given the same lifestyle and diet pattern was practiced before the merging of the country in the 1990's, one would probably not expect to see much difference in terms of aesthetic needs in seeking treatment in this cohort. However, such may not be the case in children born in the era of progressive nation development and modernisation in the future.

5.4.2.2 Aesthetic Component (AC) Assessment by Subjects

In general, the population studied showed a much lower self-perceived need for treatment (4.7%) than that assessed by the examiner (10.1%). This finding was comparable to the Turkish (Üçüncü and Ertugay, 2001) (4.8%), Iranian (Hedayati et al., 2007) (4.1%), and Brazilian (Dias and Gleiser, 2010) (5.1%) studies but lower than that reported in the Norwegian (Birkeland et al., 1996) (9%) study. These differences in orthodontic treatment need between Norwegian and Yemeni adolescents might be due to different public health programmes and care in schools. Norway is a developed country, with advance health programmes and services compared with Yemen, thus the Norwegians may have more knowledge and awareness of oral health and orthodontic treatment than Yemeni adolescents.

Interestingly, statistically significant observation was recorded by zones and gender. Yemeni adolescents living in the mountains and less developed (desert) east zones and, males showed less concern to look attractive. The latter finding was similar to that

reported by Abu Alhaija et al., (2005b) in their study among Jordanian population. This may be related to the Arab culture, whereby males showed less anxiety about their attractiveness than females especially in less developed areas. The status and position of male in society depend on his income and attitudes, while for female it rests more on beauty and good looks.

5.5 Relationship of Orthodontic Treatment Need Assessment between Examiner and Subjects

Assessment of orthodontic treatment need by examiner and subjects in this study showed significant differences. In general, the examiner perceived more adolescents in 'definite' and 'borderline' need for orthodontic treatment than as perceived by the subjects.

In this study 26.8% of the sample was assessed normatively (DHC measurement) to be in 'definite' orthodontic treatment need group. However, only 4.7% of the subjects perceived needing treatment when measured using the aesthetic component (AC). The difference between normative and subjective orthodontic treatment need was similar in studies conducted by Abdullah and Rock (2001), Hedayati et al. (2007), and Dias and Gleiser (2010).

The above observation could probably be explained as follows:

- First, most of the occlusal traits measured normatively were based on anatomical or functional features of the occlusion. However, not all of these occlusal traits were considered to be unattractive in occlusion profile. For example crossbite or partially erupted teeth were found not to attract a high aesthetic component score. This could be seen in our results when a third of the Yemeni adolescents (33.1%) were assessed to be in definite and borderline normative need for

treatment by orthodontist but they perceived to be no need for treatment (Table 4.53).

- Second, during clinical examination, a number of subjects were found to face difficulty in assessing their dentition to fit into one of the standard intraoral photographs of Aesthetic Component of IOTN. Many adolescents tried to score their occlusion to be approximately close to the photos. This observation agreed with that of a study done by Freer and Freer (1999) who found some cases being under-estimated for treatment need when measured using Aesthetic Component. On the other hand, subjects faced difficulty when assessing their dentition as several occlusal traits measured in this study had occlusal features that were not included in the Aesthetic Component. Some examples included; ≥ 2 mm general spacing (2.9%), ≥ 2 mm diastema (5.4%), anterior crossbite (2%), anterior openbite (4.5%), and all Class III cases.

Assessing aesthetic need for orthodontic treatment could be quite complex, as observed by the low correlation and significant differences found in the opinion between examiner and subjects according to Aesthetic component of IOTN measurement (Appendix 25). In this study, the examiner perceived more adolescents to be in 'definite' (10.1%) or in 'borderline' (18.8%) need of treatment than the subjects (8.7% and 4.7%, respectively). This finding was similar to that reported by Shaw et al. (1975), Chi et al. (2000), Mandall et al. (2001), Grzywacz, (2003), Hedayati et al. (2007), Kolawole et al. (2008), Dias and Gleiser (2010). Shaw (1981) was of the opinion that patient's assessment of treatment need did not always coincide with professional's assessment, because professionals often have a tendency to have a more critical view of malocclusion and the treatment needed. On the other hand, adolescents with malocclusion might not even be aware that they had a malocclusion. Perhaps the above reasons explained why the examiner an orthodontist, assessed two times more Yemeni

adolescents (28.9%) needed treatment as compared to that perceived by the subjects (13.4%), (Table 4.48).

5.6 Prevalence of Malocclusion as Measured by Different Methods

Admittedly, assessment of occlusal traits is required more in treating individual orthodontic cases. Knowledge of total prevalence of malocclusion is significantly important for population based assessment of needs for decision makers in the government to assess the magnitude of the malocclusion problem in the population. Malocclusion based on level of severity can have more direct impact to the people. It was also mentioned that malocclusion is positively associated to the appearance of unhappiness, neglected oral health, negative social behaviour, and less self-esteem (Badran, 2010).

This study reported a 74.4% prevalence of malocclusion among Yemeni adolescents based on the FDI/WHO method which took into consideration assessment of occlusal traits. The remaining proportion (25.6%) was classified as having normal occlusion (Figure 4.2). These findings were found to be comparable to several studies. Thilander and Myrberg (1973) reported a 73.8% malocclusion among 13 year-old Swedish children. Martins and Lima (2009) who used the occlusal relationship in anterio-posterior relationship by Angle Classification reported a 74.2% of malocclusion among Brazilian children. In another study which used Angle Classification Borzabadi-Farahani and co-workers, (2009) found a 77% malocclusion among 11-14 years of Iranian school children.

On the other hand, malocclusion measured based on Index of Orthodontic Treatment Need (IOTN) hierarchy grades was found to affect 68.2% of the Yemeni adolescents (Table 4.55). This finding was found to be comparable with those by Souames et al.

(2006) who also used hierarchy of treatment need by IOTN, and reported 72% had malocclusion.

Many studies mentioned about the differences in prevalence of malocclusion as measured by conventional methods of occlusal traits and hierarchy of treatment need indices (Behbehani et al., 2005; Lux et al., 2009). To the knowledge of the author there is no previous study that reported differences in the total percentage of malocclusion as measured by conventional methods of recording occlusal traits and treatment need index. Therefore, in this study comparison of findings between the two measurements is limited to only clinical examination of dental health component and conventional methods. Finding of this study showed that the difference of malocclusion were only 6.2% (conventional method more than in IOTN) (Table 4.57). The higher prevalence of malocclusion found by the FDI/WHO method might be due to the variation in each of the measurement indicator. For example, maxillary diastema and general spacing of ≥ 2 mm were measured in the conventional method of FDI/WHO, but not recorded by IOTN. Perhaps if these two malocclusion traits were included in the Dental Health Component (DHC) of IOTN, the differences of malocclusion prevalence between the two methods may not exist or could be decreased.

5.7 Modification of Orthodontic Measurement Tool for Yemeni Population

Considering the increasing demand for orthodontic treatment in Yemen, a standard measurement to assess malocclusion should be given priority service for treatment need. This become more important if the expected transformation on provision of oral health services for the population is to take place in the near future. Currently, only patients within Class II or III occlusal relationship are entered into the waiting list. This may not be accurate and not fair for patients because there are also many cases when assessed

were found to be in 'definite' need for orthodontic treatment, although they were in the Class I antero-posterior occlusal relationship (Appendix 27).

Generally, the Index of Orthodontic Treatment Need seemes to be a widely used measurement tool in the literature to estimate real treatment needs in different ethnic backgrounds. This measurement was found to be a more popular epidemiological tool in the Middle Eastern countries. In Yemen it may be timely to use this measurement tool to determine treatment need priority. This study showed that when using the conventional method certain occlusal traits among Yemeni adolescents were present, which were not shown by IOTN. This may have an impact in the actual estimation of malocclusion.

In the investigator's opinion, it is very important for Yemeni population to have a modification of IOTN because the results showed some malocclusion traits such as diastema ≥ 2 mm (5.4%), spacing ≥ 2 mm (2.9%) and bimaxillary protrusion with incompetent lip which were not measured by IOTN nor considered as Grade 1 (extremely minor malocclusion or normal occlusion). So, the modification of IOTN will measure all occlusal traits found in Yemeni population and can be used to assist the orthodontist to prioritise treatment need.

In modifying the index, our suggestion is to add measurement of malocclusion traits in Dental Health Component grades 2, 3 and 4 as follows:

4.md Maxillary diastema greater than 4 mm.

4.gs General spacing greater than 4 mm.

3.md Maxillary diastema greater than 2 mm but less than or equal to 4 mm.

3.gs General spacing greater than 2 mm but less than or equal to 4 mm.

3.bp Presence of bimaxillary protrusion with incompetent lips.

2.md Maxillary diastema greater than 1 mm but less than or equal to 2 mm.

2.gs General spacing greater than 1 mm but less than or equal to 2 mm.

2.bp Presence of bimaxillary protrusion with competent lips.

Kerosuo and co-workers (2004) studied 14-18 year-old Arab high school students in Kuwait and suggested that Aesthetic Component is a good indicator for self-perceived treatment need. Although the Aesthetic Component of IOTN had been accepted as a reliable tool to measure perceived treatment need by orthodontist and subjects, however we would like to suggest some modification to it to avoid the occurrence of some problems during examination as observed in this study. Our suggestion is to add photographs in the treatment need categories (no, borderline, and definite) of the Aesthetic Component. By doing so, the AC measurement should contain three vertical rows of photographs with each row containing five photographs slightly smaller in width than that of the standard photographs. The suggested rows are as follows:

Row 1: (No need treatment) contains 1 - 4 of Aesthetic Component photographs plus one photo of maxillary diastema with normal alignment teeth.

Row 2: (Borderline treatment need) contains 5 - 7 of Aesthetic Component photographs plus two photos. One photograph illustrates the general spacing of 4 mm, and the other one to show anterior crossbite.

Row 3: (Definite treatment need) contains 8 - 10 Aesthetic Component photographs plus two additional photos. One photograph illustrates Class III case, and the other one shows anterior openbite.

5.8 The Need for Orthodontists to Improve Orthodontic Services in Yemen

Yemen is a fast growing country with a population of approximately 20 million and average annual population growth rate of 3.02. The dental health service in Yemen is still in its infancy despite having five dental schools. These schools are mainly concentrated in the capital and other large cities, thus provision of treatment has been mostly to those living in these areas. As Yemen transforms into a modern nation, it is not impossible to expect these adolescents living in rural areas to demand orthodontic treatment too. Findings from this study are therefore relevant to highlighting the problem of malocclusion today as a preparation towards future provision for orthodontic services. Decision making is best when it is based on scientific data.

Understanding orthodontic treatment required for the population is also important when planning for future orthodontists needed to provide the services. Using Linder-Aronson (1974) model and based on the following consideration:

- Number of adolescents aged 14 years old in Yemen = 258314
- Normative orthodontic treatment need calculated in this study = 26.8%
- Treatment time for patients is about two years (Richmond et al., 1993). The average time per appointment is about 30 minutes. Assuming monthly visits, the amount of time expended to treat each patient will be 12 hours during a period of 2 years, or 6 hours per annum.

Total time need for specialists treatment $= \frac{258314 \times 26.8 \times 6}{100} =$ 415368 hours per annum.

- Specialist ability to provide 1400 treatment hours in year (Linder-Aronson, 1974).

The minimum number of orthodontists needed was calculated to be

$$\frac{\text{Total time need for specialists treatment in hours per year}}{\text{Treatment time provided by per specialist per year}} = \frac{415368}{1400} = 297$$

The above finding (297 orthodontists) can be translated as the minimum number of orthodontist specialist needed to be trained to need the orthodontic need of 14-year-olds. The number is probably larger if the whole population of children and adults are to be considered. A more accurate figure can only be determined if data is available for the whole Yemeni population. This number reflects the ideal for 14-year-olds. Considering currently available dental services in Yemen are limited, priority should be given to severe malocclusion cases until more specialists are trained. Similarly, a more realistic number of orthodontists required will also have to take into consideration the perceived need of treatment by the population.

In addition to the above, perhaps it is also timely to develop second level personnel dental therapists into the future oral health delivery system of Yemen, at the moment Yemen do not have any form of formal trained auxiliaries. Malocclusion to a certain extent is preventable; have leading to a reduction in the prevalence of orthodontic need for treatment (Al-Azemi and Artun, 2010). Dental therapists are relevant as they can provide information in the form of dental education and promotion to the general population. By so doing, the orthodontic need of the country can be handled in two directions:

- Preventative as a primary care action.
- Curative by orthodontists for those in 'definite' need for treatment.

5.9 Limitations of This Study

In this study, measurements of occlusal traits were done without taking radiographs, although anomalies such as impacted teeth, congenitally missing teeth and bimaxillary protrusion would be best diagnosed accurately using radiographs. This study used the FDI criteria to differentiate between various reasons for the missing teeth and to determine bimaxillary protrusion. This is because it is impossible to use radiographs in

national epidemiological study with a large sample size and covering the whole country. Thus the findings observed could be an under estimation of the actual need for treatment.

Although Aesthetic Component (AC) of IOTN found better indicator of an individual's perception than questionnaire for dental attractiveness (Holmes, 1992) but during this study there were some limitations in the use of Aesthetic Component. These were related to the inability of a number of subjects to evaluate their dentition with any grades of AC. In addition, the Aesthetic Component photographs show only the teeth and this may have presented as another of its limitation.

Results of present study were limited to 14-year-olds and malocclusion in the permanent dentition stage. Assessment of malocclusion of other (older as well as younger) age groups would also be useful if the national need assessment were to be estimated. The minimum number of orthodontists calculated earlier realistically only for 14 year-old, a larger number may be needed.

This study also has its limitation when considering the way the sample was selected. It is recognised that a proportion based distribution between rural and urban may improve the estimation of malocclusion. Given the large land mass, geographical terrains (coastal, islands, desert, plateau and mountains) of Yemen and a single examiner, it will require more time, money and logistic planning of school selection to do within the time frame given for data collection. This become more critical as rural schools in the desert, and mountains are far apart, not easy to access by road. In addition, the number of children in rural schools are small these will require more schools to be selected.

CHAPTER SIX

CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

Based on the findings in this study, the following conclusions were made:

1. Crowding was the most common occlusal trait found among Yemeni adolescents, commonly recorded in the mandible, whilst spacing was found in a small proportion of the sample mainly in the maxilla.

2. Based on the Angle Classification measurement of molar relationship, the prevalence of Class I, Class II and Class III were in descending order of proportions. However Class II was nine times as common as Class III malocclusion.

3. Females had a significantly higher prevalence of anterior and posterior openbite than males. This pattern suggests that female might have higher vertical facial proportion.

4. Clinically assessed normative 'definite' and 'borderline' need for orthodontic treatment was 3.5 times more than the self-perceived need by the subjects.

5. Need for treatment as perceived by the subjects was found to be very low. On the contrary, the need for treatment was perceived to be almost two and half times by the examiner.

6. The subjects' perception of their need for orthodontic treatment was found to be influenced by gender. Males tended to score their dentition towards being at the less attractive end of the scale compared with females.

7. No differences were observed in the prevalence of occlusal traits and orthodontic treatment need between subjects in urban and rural areas. This could be attributed to the similar culture and lifestyle of both groups.

8. Prevalence of malocclusion measured either by conventional method or IOTN indicated a need to prioritise treatment accordingly.

9. When comparing the prevalence of malocclusion identified by both the conventional method and hierarchy criteria of IOTN, the conventional method showed a higher proportion of subjects with malocclusion. The difference was 6.2%.

10. Other occlusal traits not included in the IOTN, such as diastema ≥2 mm, spacing ≥2 mm, and bimaxillary protrusion with incompetent lip, were also observed to be more prevalent in the Yemeni population. These features could have also contributed to the apparently lower percentage of malocclusion found.

11. Given the above findings, the IOTN appears to be suitable for further use in Yemeni and Middle Eastern populations, with modifications to include malocclusion traits mentioned in (10).

6.2 Recommendations

This study being the first of its kind, carried out on a national scale has contributed to the development of a database bank very much needed in Yemen. Findings of malocclusion and orthodontic treatment need have important implications in terms of future research as well as in the planning for orthodontic care in the country.

In line with these, the following recommendations are made:

- Further studies to be carried out to include subjects in younger and older age groups to allow correlation analysis of occlusal features. This may include investigations of oral habits among children that may affect their occlusion.

- A similar cross-sectional study with radiographic examinations to assess dental discrepancies such as impactions and congenitally absent teeth, with cephalometric study to measure vertical relationship differences between male and female.

- A longitudinal study starting from deciduous dentition to investigate the possible variation in occlusal features in the three stages of dentitions (deciduous, mixed, and permanent).

- To assess the validity of IOTN components with currently suggested modifications in the Yemeni population.

- Inclusion of IOTN in the teaching of undergraduate orthodontics in dental schools in Yemen, and utilisation of the modified IOTN to prioritie cases for orthodontic treatment.

- Use of the present data as a basis to determine manpower and resources needed to achieve adequate orthodontic care in Yemen.

- Further work will be needed to develop a strong argument to plan resources for orthodontic care in Yemen.

- A follow up national study to be done in ten years to determine any changes in the prevalence of malocclusion and orthodontic treatment need using the validated modified IOTN specific to Yemeni population.

REFERENCES

Abdul Kadir, R. (1989). Panduan kaedah epidemiologi pergigian, (methodology guidance of epidemiology dentistry). Dewan Bahasa dan Pustaka, (In Malay language) pp 25-27.

Abdullah, M.S. and Rock, W.P. (2001). Assessment of orthodontic treatment need in 5,112 Malaysian children using the IOTN and DAI indices. *Community Dent Health;* **18:** 242-248.

Abdullah, M.S. and Rock, W.P. (2002). Perception of dental appearance using index of treatment need (aesthetic component) assessments. *Community Dent Health*; **19:**161-165.

Abu Alhaija, E.S.J., Al-Nimri, K.S. and Al- Khateeb, S.N. (2004). Orthodontic treatment need and demand in 12-14 year old north Jordanian school children. *Eur J Orthod*; **26:** 261-263.

Abu Alhaija, E.S.J., Al-Khateeb, S.N. and Al-Nimri, K.S. (2005a). Prevalence of malocclusion in 13-15 year-old north Jordanian school children. *Community Dent Health*; **22:** 266-271.

Abu Alhaija, E.S.J., Al-Nimri, K.S. and Al-Khateeb. S.N. (2005b). Self-perception of malocclusion among north Jordanian school children. *Eur J Orthod*; **27:** 292-295.

Agou, S., Locker, D., Muirhead, V., Tompson, B. and Streiner, D.L. (2011). Does psychological well-being influence oral-health-related quality of life reports in children receiving orthodontic treatment?. *Am J Orthod and Dentofacial Orthop*; **139:** 169-377.

Ajayi, E.O. (2008). Orthodontic treatment need in Nigerian children. *Community Dent Health*; **25:** 126-8.

Aktan, A.M., Kara, İ., Şener, İ., Bereket, C., Celik, S., Kirtay, M., Ciftçi, M.E. and Arici, N. (2011). An evaluation of factors associated with persistent primary teeth. *Eur J Orthod*; *doi:10.1093/ejo/cjq189.* pp1-5.

Al-Azemi, R. and Artun, J. (2010). Orthodontic treatment need in adolescent Kuwaitis: prevalence, severity and manpower requirements. *Med Princ Pract*; **19:** 348-354.

Al-Emran, S., Wisth, P.J. and Boe, O.E. (1990). Prevalence of malocclusion and need for orthodontic treatment in Saudi Arabia. *Community Dent and Oral Epidemiol*; **18:** 253-255.

Al-Haddad, K.A., Al-Hebshi, N.N. and Al-Ak'hali, M.S. (2009). Oral health status and treatment needs among school children in Sana'a City, Yemen. *Int J Dent Hygiene*; **8:** 80-85.

Allen, N.D. (1970). Handicapping malocclusion assessment record in direct mouth examination. *Am J Orthod*; **58:** 67-72.

Al-Sarheed, M., Bedi, R. and Hunt, N.P. (2003). Orthodontic treatment need and self-perception of 11–16-year-old Saudi Arabian children with a sensory impairment attending special schools. *J Orthod*; **30:** 39-44.

Andrews, L.F. (1972). The six keys to normal occlusion. *Am J Orthod and Dentofacial Orthop*; **62:** 296-309.

Angle, E.H. (1899). Classification of malocclusion. *Dent Cosmos;* **41:** 248-64, 350-357.

Annual Statistical Health Report, 2008. A series of reports and researches. Ministry of Health Press Ltd. Yemen. [In Arabic Language], pp 45-170.

Arruda, A.O. (2008). Occlusal indexes as judged by subjective opinions. *Am J Orthod and Dentofacial Orthop*; **134:** 671-675.

Ash, M.M. and Nelson, S.J. (2003). Dental anatomy, physiology, and occlusion. Eight ed. Elsevier Science (USA), pp 437-488.

Backlund, E. (1958). Overbite and the incisor angle. *Trans Eur Orthod Soc*; 277-286.

Badran, S.A. (2010). The effect of malocclusion and self-perceived aesthetics on the self-esteem of a sample of Jordanian adolescents. *Eur J Orthod*; **32:** 638-644.

Baharon M.R. (1999). Assessment of malocclusion and orthodontic treatment need of 16- year-old schoolchildren in Batu Pahat, Johore. M.Sc. Thesis, University Malaya.

Ballard, C.F. and Wayman, J.B. (1965). A report on a survey of the orthodontic requirements of 310 army apprentices. *Dent Pract Dent Rec*; **15:** 221-226.

Baume, L.J., Horowitz, H.S., Summers, C.J., Bcker, Dirkes, O., Carlos, J.P. and Cohen, L.K. (1973). A method for measuring occlusal traits developed by the FDI commission on classification and statistics for oral conditions. *Int Dent J*; **23:** 530-537.

Beglin, F.M., Firestone, A.R., Vig, K.W., Beck, F.M., Kuthy, R.A. and Wade, D. (2001). A comparison of the reliability and validity of 3 occlusal indexes of orthodontic treatment need. *Am J Orthod and Dentofacial Orthop*; **120:** 240-246.

Behbehani, F., Årtun, J., Al-Jame, B., and Kerosuo, H. (2005). Prevalence and severity of malocclusion in adolescent Kuwaitis. *Med Princ Pract*; **14:** 390-395.

Bergström, K. and Halling, A. (1997). Comparison of three indices in evaluation of orthodontic treatment outcome. *Acta Odontol Scand*; **55:** 36-43.

Bernabé, E. and Flores-Mir, C. (2006a). Normative and self-perceived orthodontic treatment need of a Peruvian university population. *Head & Face Medicine*; **2:** 22.

Bernabé, E. and Flores-Mir, C. (2006b). Dental morphology and crowding: A multivariate approach. *Angle Orthod*; **76:** 20-25.

Beyron H.L. (1954). Characteristics of functionally optimal occlusion and principles of occlusal rehabilitation. *J Am Dent Assoc;* **48:** 648-456.

Bezroukov, V., Freer, T.J., Helm, S, Kalamkarov, H., Sardo Infirri, J. and Solow, B. (1979). Basic method for recording occlusal traits. *Bulletin World Health Organisation*; **57:** 955-961.

Birkeland, K., Bøe, O.E., Wisth, P.J. (1996). Orthodontic concern among 11-year-old children and their parents compared with orthodontic treatment need assessed by index of orthodontic treatment need. *Am J Orthod and Dentofacial Orthop*; **110:** 197-205.

Björk, A., Krebs, A.A. and Solow, B. (1964). A method for epidemiological registration of malocclusion. *Acta Odontol Scand*; **22:** 27-41.

Bollen, A.M. (2008). Effects of malocclusions and orthodontics on periodontal health: Evidence from a systematic review. *J Dent Educ*; **72:** 912-918.

Borzabadi-Farahani, A., Borzabadi-Farahani, A., and Eslamipour, F. (2009). Malocclusion and occlusal traits in an urban Iranian population. An epidemiological study of 11- to 14-year-old children. *Eur J Orthod*; **31:** 477-484.

Brin, I., Weinberger, T. and Ben-Chorin, E. (1999). Classification of occlusion reconsidered. *Eur J Orthod*; **21:** 169-174.

British Standard Institute. (1983). British Standard Incisor Classification, Glossary of Dental Terms BS-4492, British Standard Institute, London.

Brook, P.H. and Shaw, W.C. (1989). The development of an index of orthodontic treatment priority. *Eur J Orthod*; **11:** 309-320.

Brunelle, J.A., Bhat, M. and Lipton, J.A. (1996). Prevalence and distribution of selected occlusal characteristics in the US population, 1988-1991. *J Dent Res*; **75:** 706-713.

Burden, D.J. and Pine, C.M. (1995). Self-perception of malocclusion among adolescents. *Community Dent Health*; **12:** 89-92.

Burden, D.J., Mitropoulos, C.M. and Shaw, W.C. (1994). Residual orthodontic treatment need in a sample of 15- and 16-year-olds, *Br Dent J;* 1**76:** 220-224.

Burden, D.J. (1995). Need for orthodontic treatment in Northern Ireland. *Community Dent and Oral Epidemiol*; **23:** 62-63.

Burden, D.J. and Holmes, A. (1994). The need for orthodontic treatment in the child population of the United Kingdom. *Eur J Orthod*; **16:** 395-399.

Campbell, M.J., Machin D. and Walters, S.J. (2007). Medical statistics: A textbook for the health sciences. 4th edition, United Kingdom: Wiley. pp 9-12.

Caplan, M.J. (1997). The effect of premolar extraction on the soft-tissue profile in adult African American females. *Angle Orthod*; **67:** 129-136.

Cassidy, K.M., Harris, E.F. Tolley, E.A. and Keim, R.G. (1998). Genetic influence on dental arch form on orthodontic patients. *Angle Orthod*; **68:** 445-454.

Central Statistical Organisation Report, (2004). The report of central statistical organisation, Ministry of Planning and Int. Coop. In statistical book of Yemen, pp 23-36.

Chi, J., Harkness, M. and Crowther, P. (2000). A longitudinal study of orthodontic treatment need in Dunedin schoolchildren. *N Z Dent J*; **96:** 4-9.

Chu, C.H., Choy, B.H. and Lo, E.C. (2009). Occlusion and orthodontic treatment demand among Chinese young adults in Hong Kong. *Oral Health Prev Dent*; **7:** 83-91.

Chung, C.J., Han, J.H. and Kim, K.H. (2008). The pattern and prevalence of hypodontia in Koreans. *Oral Dis*; **14:** 620-625.

Ciger, S. and Akan, S. (2010). Occlusal characteristics of deaf-mute individuals in the Turkish population. *Eur J Dent*; **4:** 128-136.

Ciuffolo, F., Manzoli, L., D'Attilio, M., Tecco, S., Muratore, F., Festa, F. and Romano, F. (2005). Prevalence and distribution by gender of occlusal characteristics in a sample of Italian secondary school students: a cross-sectional study. *Eur J Orthod;* **27:** 601-606.

Cons, N.C., Jenny, J. and Kohout, F.J. (1986). DAI: The Dental Aesthetic Index. College of Dentistry, University of Iowa, Iowa.

Cons, N.C., Mruthyunjaya, Y.C. and Pollard, S.T. (1978). Distribution of occlusal traits in a sample of 1337 children Aged 15-18 residing in Upstate New York. *Int Dent J*; **28:** 154-164.

Cooke, M.S. and Chawla, H.S. (1981). The quantitative assessment of incisor overbite: Preliminary report of a new silicone squash bite technique which has epidemiological and detailed biometric application. *J Dent*; **9:** 58-66.

Cooper, S., Orth, M., Mandall, N.A., Dibuise, A. and Shaw, W.C. (2000). The reliability of the index of orthodontic treatment need over time. *Am J Orthod;* **27:** 47-53.

Crabb, J.J. and Rock, W.B. (1986). Orthodontic screening of nine-year old children. *Br J Orthod*; **13:** 43-47.

Cruz, R.M., Krieger, H., Ferreira, R., Mah, J., Jr. J.H. and Oliveira. S. (2008). Major gene and multifactorial inheritance of mandibular prognathism. *Am J Med Genetics*; **146A:** 71-77.

Da Silva J.D., Mitchell, D. A. and Mitchell, L. (2008). Oxford American Handbook of Clinical Dentistry. Oxford University Press. Inc. New York, pp 126.

Danaei, S.M. and Salehi, P. (2010). Association between normative and self-perceived orthodontic treatment need among 12- to 15-year-old students in Shiraz, Iran. *Eur J Orthod*; **32:** 530-534.

Daniels, C.P. and Richmond, S. (2000). The development of the Index of Complexity Outcome and Need (ICON). *J Orthod*; **27:** 149-162.

Danyluk, K., Lavelle, C. and Hassard, T. (1999). Potential application of the dental aesthetic index to prioritize the orthodontic service needs in a publicly funded dental program. *Am J Orthod and Dentofacial Orthop*; **116:** 279-286.

Davis, P.J. (1987). Hypodontia and hyperdontia of permanent teeth in Hong Kong school children. *Community Dent and Oral Epidemiol*; **15:** 218-220.

Dhar, V., Jain, A., Van Dyke, T.E, and Kohli, A. (2007). Prevalence of gingival diseases, malocclusion and fluorosis in school-going children of rural areas in Udaipur district. *J Indian Soc Pedod Prev Dent;* **25:** 103-105.

Diagne, F., Ba, I., Ba-Diop, k., Yam. A.A., and Ba-Tamba, A. (1993). Prevalence of malocclusion in Senegal. *Community Dent and Oral Epidemiol*; **21:** 325-326.

Dias, P.F. and Gleiser, R. (2010). Orthodontic concerns of Brazilian children and their parents compared to the normative treatment need. *J Oral Sci*; **52:** 101-107.

Draker, H.L. (1960). Handicapping labio-lingual deviations proposed for public health purposes. *Am J Orthod*; **46:** 295-305.

Du, S.Q., Rinchuse, D.J., Zullo, T.G. and Rinchuse, D.J. (1998). Reliability of three methods of occlusion classification. *Am J Orthod and Dentofacial Orthop*; **113:** 463-470.

Eismann, D. (1974). A method of evaluating the efficiency of orthodontic treatment. *Trans Eur Orthod Soc*, pp 223-232.

Ekuni, D., Furuta, M., Irie, K., Azuma, T., Tomofuji, T., Murakami, T., Yamashiro, T., Ogura, T. And Morita, M. (2011). Relationship between impacts attributed to malocclusion and psychological stress in young Japanese adults. *Eur J Orthod*; *doi:10.1093/ejo/cjq121*. (Abstract).

Elderton, R.J. and Clark, J.D. (1983). Orthodontic treatment in the general dental service assessed by the occlusal index. *Br J Orthod*; **10:** 178-186.

El-Mangoury, N.H. and Mostafa, Y.A. (1990). Epidemiologic panorama of dental occlusion. *Angle Orthod*; **60:** 207-213.

Esa, R. and Razak, I.A. (1998) Orthodontic treatment seed in a sample of 12-13 year-old Malaysian schoolchildren according to the Dental Aesthetic Index. J Dent Res **78:** (5) 1170, [Abstract]. Proceeding of the 13th International Association of Dental Research. South East Asian Division. Kuala Lumpur.1-3 October 1998.

Esa, R., Razak, I.A. and Allister, J.H. (2001). Epidemiology of malocclusion and orthodontic treatment need of 12-13-year-old Malaysian schoolchildren. *Community Dent health*; **18:** 31-36.

Espeland, L.V., Ivarson, K. and Starvick, A. (1992). A new Norwegian index of orthodontic treatment need to orthodontic concern among 11-year olds and their parents. *Community Dent and Oral Epidemiol*; **20:** 274-279.

Evans, R., Shaw, W.C. (1987). Preliminary evaluation of an illustrated scale for rating dental attractiveness. *Eur J Orthod*; **9:** 314-318.

Evensen, J.P. and Øgrade, B. (2007). Are malocclusions more prevalent and sever now? A comparative study of medieval skulls from Norway. *Am J Orthod and Dentofacial Orthop*; **131:** 710-716.

Ezoddini, A.F., Sheikhha, M.H. and Ahmadi, H. (2007). Prevalence of dental developmental anomalies: A radiographic study. *Community Dent Health*; **24:** 140-144.

Farčnik, F., Korpar, M., Premik, M. and Zorec, R. (1985). Numerical evaluation of malocclusion in study models of the mixed dentition. *Zobozdravstveni Vestnik*; **40:** 169-176. [Article in Croatian], (cited by Ovsenik, 2007).

Farčnik, F., Korpar, M., Premik, M. and Zorec, R. (1988). An attempt at numerically evaluating dysgnathias in the deciduous dentition. *Stomatologie der DDR;* **38:** 386-391. [Article in German], (cited by Ovsenik, 2007).

Farrow, A.K., Zarrinnia, K. and Azizi, K (1993). Bimaxillary protrusion in black Americans an aesthetic evaluation and the treatment considerations. *Am J Orthod and Dentofacial Orthop*; **104:** 240-250.

Fekonja, A. (2005). Hypodontia in orthodontically treated children. *Eur J Orthod*; **27:** 457-460.

Finnoy, P.J. Wisth, P.J. and Boe, O.E. (1987). Changes in soft tissue profile during and after orthodontic treatment. *Eur J Orthod*; **9:** 68-78.

Foster, T.D. (1990). A textbook of orthodontics. 3nd ed. Blackwell Scientific Publications, pp. 24-31.

Foster, T.D. and Day, A.J.W. (1974). A survey of malocclusion and the need for orthodontic treatment in a Shropshire school population. *Br J Orthod*; **1:** 73-78.

Foster, T.D. and Menezes, D.M. (1976). The assessment of occlusal features for public health purposes. *Am J Orthod;* **63:** 83-90.

Freer, E. and Freer, T.J. (1999). Variations in treatment need using four screening methods. *Aust Orthod J*; **15:** 214-218.

Gábris, K., Márton, S. and Madléna, M. (2006). Prevalence of malocclusions in Hungarian adolescents. *Eur J Orthod;* **28:** 467-470.

Gardiner, J.H. (1982). An orthodontic survey of Libyan schoolchildren. *Br J Orthod*; **9:** 59-61.

Garner, L.D. and Butt, M.N. (1985). Malocclusion in black Americans and Nyeri Kenyans - an epidemiologic study. *Angle Orthod*; **55:** 139-146.

Gelgör, İ.E., Karaman, A.İ. and Ercan, E. (2007). Prevalence of malocclusion among adolescents in central Anatolia. *Eur J Dent*; **1:** 125-131.

Ghafari, J., Locke, S.A. and Bentley, J.M. (1989). Longitudinal evaluation of the Treatment Priority Index (TPI). *Am J Orthod and Dentofacial Orthop*; **96:** 382-389.

Gilmore, C.A. and Little, R.M. (1984). Mandibular incisor dimensions and crowding. *Am J Orthod*; **86:** 493-502.

Gomes, R.R., da Fonseca, J.A., Paula, L.M., Faber, J. and Acevedo, A.C. (2010). Prevalence of hypodontia in orthodontic patients in Brasilia, Brazil. *Eur J Orthod*; **32:** 302-306.

Gosney, M.B. (1986). An investigation into some of the factors influencing the desire for orthodontic treatment. *Br J Orthod*; **13:** 87-94.

Grainger, R.M. (1967). Orthodontic treatment priority index. Public Health Service Publication no. 1000, Series 2, No. 25. Government Printing Office, Washington DC.

Grainger, R.M. (1961). Malocclusion severity estimate. *Progress Report*, Series V1. Burlington Orthod Research Centre; pp 9-11.

Gravely, J.F. and Johnson, D.B. (1974). Angle's classification of malocclusion: An assessment of reliability. *Br J Orthod*; **1:** 79-86.

Gray, A.S. and Demirjian, A. (1977). Indexing occlusion for dental public health programs. *Am J Orthod*; **72:** 191-197.

Grytten, J., Skau, I, and Stenvik, A. (2010). Distribution of orthodontic services in Norway. *Community Dent and Oral Epidemiol*; **38:** 267-273.

Grzywacz, I. (2003). The value of the aesthetic component of the index of orthodontic treatment need in the assessment of subjective orthodontic treatment need. *Eur J Orthod*; **25:** 57-63.

Hamdan, A.M. (2001). Orthodontic treatment need in Jordanian school children. *Community Dent Health*; **18:** 177-180.

Hans, M.G., Groisser, G., Damon, C., Amberman, D., Nelson S. and Palomo, J.M. (2006). Cephalometric changes in overbite and vertical facial height after removal of 4 first molars or first premolars. *Am J Orthod and Dentofacial Orthop*; **130:** 183-188.

Harris, E.F. and Johnson, M.G. (1991). Heritability of craniometric and occlusal variables: a longitudinal sib analysis. *Am J Orthod and Dentofacial Orthop*; **99:** 258-268.

Hassan, A.H. (2006). Orthodontic treatment need in the western region of Saudi Arabia: a research report. *Head and Face Med;* **2:** 2-2.

Hassan, A.H. and Amin, H.E. (2010). Association of orthodontic treatment needs and oral health-related quality of life in young adults. *Am J Orthod and Dentofacial Orthop*; **137:** 42-47.

Hassan, R. and Rahimah, A.K. (2007). Occlusion, malocclusion and method of measurements - an overview. *Archives of Orofacial Sciences*; **2:** 3-9.

Haynes, S. (1972). The distribution of overjet and overbite in English children 11-12 years. *Dent Pract Dent Rec*; **22:** 380-383.

Haynes, S. (1973): Orthodontic treatment needs in English children aged 11 to 12 years. *Br J Orthod*; **1:** 9-12.

Hedayati, Z., Fattahi, H.R., and Jahromi, S.B. (2007). The use of index of orthodontic treatment need in an Iranian population. *J Indian Soc Pedod Prev Dent*; **25:** 10-14.

Helm, S. (1968). Malocclusion in Danish children with adolescent dentition: An epidemiologic study. *Am J Orthod*; **54:** 352-366.

Hill, P.A. (1992). The prevalence and severity of malocclusion and the need for orthodontic treatment in 9-, 12-, and 15-year-old Glasgow schoolchildren. *Br J Orthod*; **19:** 87-96.

Hoenig, J.M. and Heisey, D.M. (2001). The abuse of power: The pervasive fallacy of power calculations for data analysis. *Am Statistician*; **55:** 19-24.

Holmes A. (1992). The Prevalence of orthodontic treatment need. *Br J Orthod;* **19:** 177-182.

Horowitz, H.S. (1970). A study of occlusal relations in 10- to 12-year-old Caucasian and Negro children - summary report. *Int Dent J*; **20:** 593-605.

Houston, W.J.B. (1976). Walter's orthodontics notes. 3rd ed. John Write and Sons Ltd. Bath Road, Bristol, England, pp 1-15.

Houston, W.J.B. (1983). Walter's orthodontics notes. 4rd ed. John Write and Sons Ltd. Bath Road, Bristol, England, pp 128-134.

Houston, W.J.B. and Tulley, W.J. (1986). A textbook of orthodontics, 1st Edition. Wright imprint by IOP Publishing Limited, Bristol BS1, England, pp. 1-6.

Huang, W.J. and Creath, C.J. (1995). The midline diastema: A review of its aetiology and treatment. *Pediatric Dent*; **17:** 171-179.

Hussein, E. and Abu Mois, M. (2007). Bimaxillary protrusion in the Palestinian population. *Angle Orthod*; **77:** 817-820.

Ingervall, B., Mohlin, B. and Thilander, B. (1978). Prevalence and awareness of malocclusion in Swedish men. *Community Dent and Oral Epidemiol*; **6:** 308-314.

Isiekwe, M. (1990). Prevalence of bimaxillary protrusion in a Nigerian population. *Odonto-stomatologie tropicale*; **13:** 9-12.

Isiekwe, M.C. (1983). Malocclusion in Lagos, Nigeria. *Community Dent and Oral Epidemiol*; **11:** 53-62.

Jamilian, A., Gholami, D., Toliat, M. and Safaeian, S. (2008). Changes in facial profile during orthodontic treatment with extraction of four first premolars. *Orthod Waves*; **68:** 157-161.

Jamilian, A., Toliat, M. and Etezad, S. (2010). Prevalence of malocclusion and index of orthodontic treatment need in children in Tehran. *Oral Health Prev Dent*; **8:** 339-343.

Jenny, J. and Cons, N.C. (1996). Establishing malocclusion severity levels on the Dental Aesthetic Index (DAI) Scale. *Aust Dent J*; **41:** 43-46.

Jolley, C.J., Huang, G.J., Greenlee, G.M., Spiekerman, C., Kiyak, H.A. and King, G.J. (2010). Dental effects of interceptive orthodontic treatment in a Medicaid population: Interim results from a randomized clinical trial. *Am J Orthod and Dentofacial Orthop*; **137:** 324-333.

Jones, W.B. (1987). Malocclusion and facial types in a group of Saudi Arabian patients referred for orthodontic treatment: a preliminary study. *Br J Orthod*; **14:** 143-146.

Jonsson, T., Arnlaugsson, S., Karlsson, K.O., Ragnarsson, B., Arnarson, E.O. and Magnusson, T.E. (2007). Orthodontic treatment experience and prevalence of malocclusion traits in an Icelandic adult population. *Am J Orthod and Dentofacial Orthop*; **131:** 8.e11-e18.

Jung, M. H. (2010). Evaluation of the effects of malocclusion and orthodontic treatment on self-esteem in an adolescent population. *Am J Orthod and Dentofacial Orthop;* **138:** 160-166.

Katz, M.I. (1992a). Angle classification revisited 1: Is current use reliable? *Am J Orthod and Dentofacial Orthop;* **102:** 173-179.

Katz, M.I. (1992b) Angle classification revisited 2: A modified Angle classification. *Am J Orthod and Dentfacial Orthop*; **102:** 277-284.

Katz, R.V. (1978). An epidemiologic study of the relationship between various states of occlusion and the pathological conditions of dental caries and periodontal disease. *J Dent Res*; **3:** 433-439.

Kerosuo, H., Al Enzel, S., Keronsou, G. and Abdulkarim, E. (2004). Association between normative and self-perceived orthodontic treatment need among Arab high school students. *Am J Orthod and Dentofacial Orthop*; **125:** 373-378.

Kerosuo, H., Laine, T., Kerosuo, E., Ngasapa, D. and Honkala, E. (1988). Occlusion among a group of Tanzanian urban schoolchildren. *Community Dent and Oral Epidemiol*; **16:** 306-309.

Kerosuo, H., Laine, T., Nyssonen, V. and Honkala, E. (1991). Occlusal characteristics among groups of Tanzanian and Finnish urban school children. *Angle Orthod*; **61:** 49-56.

King, G.J. and Brudvik, P. (2010). Effectiveness of interceptive orthodontic treatment in reducing malocclusions. *Am J Orthod and Dentofacial Orthop*; **137:** 18-25.

Klages, U., Bruckner, A. and Zentner, A. (2004). Dental aesthetics, self-awareness, and oral health-related quality of life in young adults. *Eur J Orthod*; **26:** 507-514.

Klages, U., Rost, F., Wehrbein, H. and Zentner, A. (2007). Perception of occlusion, psychological impact of dental aesthetics, history of orthodontic treatment and their relation to oral health in naval recruits. *Angle Orthod*; **77:** 675-680.

Kolawole, K.A., Otuyemi, O.D., Jeboda, S.O. and Umweni, A.A. (2008). Awareness of malocclusion and desire for orthodontic treatment in 11 to 14 year-old Nigerian schoolchildren and their parents. *Aust Orthod J*; **24:** 21-25.

Koochek, A.R., Yeh, M.S., Rolfe, B. and Richmond, S. (2001). The relationship between index of complexity, outcome and need, and patients' perceptions of malocclusion: A study in general dental practice. *Br Dent J*; **191:** 325-329.

Krzypow, A.B., Lieberaian, M.A. and Modan, M. (1975). Prevalence of malocclusion in young adults of various ethnic backgrounds in Israel. *J Dent Res*; **54:** 605-608.

Kusnoto, J. and Kusnoto, H. (2001). The effect of anterior tooth retraction on lip position of orthodontically treated adult Indonesians. *Am J Orthod and Dentofacial Orthop*; **120:** 304-307.

Lamberton, C.M., Reichart, P.A. and Triratananimit, P. (1980). Bimaxillary protrusion as a pathologic problem in the Thai. *Am J Orthod and Dentofacial Orthop*; **77:** 320-329.

Landis, J.R. and Koch, G.G. (1977). The measurement of observer agreement for categorical data. *Biometrics*; **33:** 159-174.

Lau, D., Griffiths, G. and Shaw, W.C. (1984). Reproducibility of an index for recording the alignment of individual teeth. *Br J Orthod*; **11:** 80-84.

Lauc, T. (2003). Orofacial analysis on the Adriatic islands: An epidemiological study of malocclusions on Hvar Island. *Eur J Orthod*; **25:** 273-278.

Lavelle, C.L.B. (1976). A study of multiracial malocclusion. *Community Dent and Oral Epidemiol*; **4:** 38-41.

Lenth R.V. (2001). Some practical guidelines for effective sample size determination. *Am Statistician*; **55:** 187-193.

Lew, K. (1989) Profile changes following orthodontic treatment of bimaxillary protrusion in adults with the Begg appliance. *Eur J Orthod*; **11:** 375-381.

Lew, K.K., Foong, W.C. and Loh, E. (1993). Malocclusion prevalence in an ethnic Chinese population. *Aust Dent J*; **38:** 442-449.

Liepa, A., Urtane, I., Richmond, S. and Dunstan, F. (2003). Orthodontic treatment need in Latvia. *Eur J Orthod*; **25:** 279-284.

Linder-Aronson, S. (1974). Orthodontics in the Swedish public dental health service. *Trans Eur Orthod Soc*; 233-240.

Louwerse, T.J., Aartman, I.H.A., Kramer, G.J. and Prahl-Andersen, B. (2006). The reliability and validity of the Index of Complexity, Outcome and Need for determining treatment need in Dutch orthodontic practice. *Eur J Orthod*; **28:** 58-64.

Lundström, A. (1977). Need for treatment in cases of malocclusion. *Trans Eur Orthod Soc*; **53:** 111-123.

Lux, C.J., Dücker, B. Pritsch, M. Komposch, G. and Niekusch, U. (2009). Occlusal status and prevalence of occlusal malocclusion traits among 9-year-old schoolchildren. *Eur J Orthod;* **31:** 294-299.

Lux, C.J., Dücker, B., Pritsch, M., Niekusch, U. and Komposch, G. (2008). Space conditions and prevalence of anterior spacing and crowding among nine-year-old schoolchildren. *J Orthod*; **35:** 33-42.

Mandall, N.A., McCord, J.F., Blinkhorn, A.S., Worthington, H.V. and O'Brien, K.D. (2000). Perceived aesthetic impact of malocclusion and oral self-perception in 14-15-year-old Asian and Caucasian children in Greater Manchester. *Eur J Orthod*; **21:** 175-183.

Mandall, N.A., Wright, J., Conboy, F.M. and O'Brien, K.D. (2001). The relationship between normative orthodontic treatments need and measures of consumer perception. *Community Dent Health*; **18:** 3-6.

Manzanera, D., Montiel-Company, J.M., Almerich-Silla, J.M. and GandÍa, J.L. (2009). Orthodontic treatment need in Spanish schoolchildren: an epidemiological study using the Index of Orthodontic Treatment Need. *Eur J Orthod*; **31:** 180-183.

Marques, L.S., Filogônio, C.A., Filogôni, C.B. and Pereira, L.J. (2009). Aesthetic impact of malocclusion in the daily living of Brazilian adolescents. *J Orthod*; **36:**152-159.

Martins, G. and Lima, K.C. (2009). Prevalence of malocclusions in 10- to 12-year-old schoolchildren in Ceará, Brazil. *Oral Health Prev Dent*; **7:** 217-223.

Massler, M. and Frankel, J.M. (1951). Prevalence of malocclusion in children aged 14 to 18 years. *Am J Orthod***; 37:** 751-768.

Mattheeuws, N., Dermaut, L. and Martens, G (2004). Has hypodontia increased in Caucasians during the 20th century? A Meta analysis. *Eur J Orthod*; **26:** 99-103.

McDonald, F. and Ireland, A.J. (1998). Diagnosis of the orthodontic patient. Oxford University Press Inc., New York, pp 140.

McGuinness, N.J., Stephens, C.D. (1994). An introduction to indices of malocclusion. *Dent Update*; **5:** 140-144.

Ministry of Education Report (2004). The report of Ministry of Education in statistical book of Yemen, pp 213-276.

Ministry of Finance Report (2004). The report of Ministry of Finance in statistical book of Yemen, pp 191-212.

Mitchell, L. (2001). An introduction of orthodontics. 2rd ed. Oxford University Press Inc, New York, pp 9-16.

Mohlin, B. (1982). Need and demand for orthodontic treatment in a group of women in Sweden. *Eur J Orthod*; **4:** 231-242.

Mossey, P.A. (1999). The heritability of malocclusion part 1 genetics, principles and terminology. *Br J Orthod*; **26:** 103- 113.

Mtaya, M., Brudvik, P. and Åstrøm, A.N. (2009). Prevalence of malocclusion and its relationship with sociodemographic factors, dental caries, and oral hygiene in 12- to 14-year-old Tanzanian schoolchildren. *Eur J Orthod*; **31:** 467-476.

Mugonzibwa, E.A., Eskeli, R., Laine-Alava, M.T., Kuijpers-Jagtman, A.M. and Katsaros, C. (2008). Spacing and crowding among African and Caucasian children. *Orthod Craniofac Res*; **11:** 82-89.

Mugonzibwa, E.A., Kuijpers-Jagtman, A.M., Van't Hof, M.A. and Kikwilu, E.N. (2004). Perceptions of dental attractiveness and orthodontic treatment need among Tanzanian children. *Am J Orthod and Dentofacial Orthop*; **125:** 426-434.

Mũniz, B.R. (1986). Epidemiology of malocclusion in Argentine children. *Community Dent and Oral Epidemiol*; **14:** 221-224.

Nance, H.N. (1947). The limitations of orthodontic treatment: I. Mixed dentition diagnosis and treatment. *Am J Orthod Oral Surg*; **33:** 177-223.

National Information Centre of Yemen, 2002. http://www.yemen nic.info/English%20site/index.htm

Ng'ang'a, P.M., Stenvik, A., Ohito, F., and Ögaard, B. (1997). The need and demand for orthodontic treatment in 13- to 15-year-olds in Nairobi, Kenya. *Acta Odontol Scand*; **55:** 325-328.

Ngom, P.I., Diagnea, F., Dieyeb, F., Diop-Baa, F. and Thiamc, F. (2007). Orthodontic treatment need and demand in Senegalese school children aged 12-13 years. *Angle Orthodontist*; **77:** 223-230.

Onyeaso, C.O. (2004). Prevalence of malocclusion among adolescents in Ibadan, Nigeria. *Am J Orthod and Dentofacial Orthop*; **126:** 604-607.

Otuyemi, O.D. and Noar, G.H. (1996a). Variability in recording and grading the need for orthodontic treatment using the handicapping malocclusion assessment record, occlusal index and dental aesthetic index. *Community Dent and Oral Epidemiol*; **24:** 222-224.

Otuyemi, O.D. and Noar, J.H. (1996b). A comparison between DAI and SCAN in estimating orthodontic treatment need. *Int Dent J*; **46:** 35-40.

Otuyemi, O.D., Ugboko, V.I., Adekoya-Sofowora, C.A. and Ndukwe, K.C. (1997). Unmet orthodontic treatment need in rural Nigerian adolescents. *Community Dent and Oral Epidemiol*; **25:** 363-366.

Ovsenik, M. (2007). Assessment of malocclusion in the permanent dentition: Reliability of intraoral measurements. *Eur J Orthod*; **29:** 654-659.

Ovsenik, M. and Primožič, J. (2007). Evaluation of 3 occlusal indexes: Eismann index, Eismann-Farčnik index, and index of orthodontic treatment need. *Am J Orthod and Dentofacial Orthop*; **131:** 496-503.

Ovsenik, M., Farčnik, F. and Verdenik, I. (2007). Intra- and inter-examiner reliability of intraoral malocclusion assessment. *Eur J Orthod*; **29:** 88-94.

Ovsenik, M., Farčnik, F. M. and Verdenik, I. (2004). Comparison of intra-oral and study cast measurements in the assessment of malocclusion. *Eur J Orthod*; **26:** 273-277.

Pair, J.W., Luke, L. and White, S., Atchinson, K., Englehart, R. and Brennan R. (2001). Variability of study cast assessment among orthodontists. *Am J Orthod and Dentofacial Orthop*; **120:** 629-638.

Parker, W.S. (1998). The HLD (CalMod) index and the index question. *Am J Orthod and Dentofacial Orthop*; **114:** 134-141.

Perillo, L., Masucci, C., Ferro, F., Apicella, D. and Baccetti, T. (2010). Prevalence of orthodontic treatment need in southern Italian schoolchildren. *Eur J Orthod;* **32:** 49-53.

Pickering, E.A. and Vig, F. (1975). The Occlusal Index used to assess orthodontic treatment. *Br J Orthod*; **2:** 47-51.

Pietilá, T. and Pietilá, I. (1996). Dental appearance and orthodontic services assessed by 15-16-year-old adolescents in eastern Finland. *Community Dent Health*; **13:** 139-144.

Pitt, S., Hamdan, A. and Rock, P. (2006). A treatment difficulty index for unerupted maxillary canines *Eur J Orthod*; **28:** 141-144.

Poonacha, K.S., Deshpande, S.D. and Shigli, A.L. (2010). Dental Aesthetic Index: Applicability in Indian population: A retrospective study. *J Indian Soc Pedod Prev Dent*; **28:** 13-17.

Poosti, M. and Jalali, T. (2007). Tooth size and arch dimension in uncrowded versus crowded Class I malocclusions. *J Contemp Dent Prac*; **8:** 45-52.

Potter, R.H., Nance, W.E., Yu, P.L. and Davis, W.B (1976). A twin study of dental dimension. II. Independent genetic determinants. *Am J Phys Anthropol*; **44:** 397-412.

Poulton, D.R. and Aaronson, S.A. (1961). The relationship between occlusion and periodontal status. *Am J Orthod*; **47:** 690-699.

Primosch, R.E. (1981). Anterior supernumerary teeth-assessment and surgical intervention in children. *Pediatr Dent*; **3:** 204-215.

Proffit, W.R, and Ackerman, J.L. (1973). Rating the characteristics of malocclusion: a systematic approach for planning treatment. *Am J Orthod*: **64:** 258-269.

Proffit, W.R., Fields, H.W. Jr. and Moray, L.J. (1998). Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. *Int J Adult Orthod Orthognath Surg*; **13:** 97-106.

Rani, M.R. (2001). Textbook of orthodontics 3rd ed. All India Publishers and Distributors Regd, Chennai, pp 32-49.

Richards, B. (2001). An approach to the diagnosis of different malocclusions. In: Textbook of orthodontics, (Bishara, S. E., eds). WB Saunders Company, Philadelphia, pp 146-184.

Richmond, S., O'Brien, K.D., Buchanan, I.B. and Burden, D.J. (1992a). An introduction to occlusal indices. Victoria University of Manchester, U.K. pp 2-13.

Richmond, S., Shaw, W.C., Robert, C.T. and Andrews, M. (1992b). The PAR Index (Peer Assessment Rating): methods to determine outcome of orthodontic treatment in terms of improvement and standards. *Eur J Orthod*; **14:** 180-187.

Richmond, S., Shaw, W.C., Stephens, C.D., Webb, W.G., Roberts, C.T. and Andrews, M. (1993). Orthodontics in the general dental service of England and Wales: A critical assessment of standards. *Br Dent J*; **174:** 315-329.

Richmond, S., Shaw, W.C., O'Brien, K.D., Buchanan, I. B., Stephens, C.D., Andrews, M. and Roberts C.T. (1995). The relationship between the index of orthodontic treatment need and consensus opinion of a panel of 74 dentists. *Br Dent J*; **178:** 370-374.

Rinchuse, D.J. and Rinchuse, D.J. (1989). Ambiguities of Angle's classification. *Angle Orthod*; **59:** 295-298.

Roth, R.H. (1981). Functional occlusion for the orthodontist. *J Clin Orthod*; **15:** 32-51.

Safavi, S.M., Sefidroodi, A., Nouri, M., Eslamian, L., Kheirieh, S. and Bagheban, A. (2009). Orthodontic treatment need in 14-16 year-old Tehran high school students. *Aust Orthod J*; **25:** 8-11.

Salaam, M. A. (2000). The democratic system in Yemen. Al-Afaq for Printing and Publishing, (In Arabic language) pp 22-30.

Salonen, L., Mohlin, B., Goötzlinger, B. and Helldén, L. (1992). Need and demand for orthodontic treatment in an adult Swedish population. *Eur J Orthod*; **14:** 359-368**.**

Salzmann, J.A. (1968). Handicapping malocclusion assessment to establish treatment priority. *Am J Orthod;* **54:** 749-765.

Santoro, M., Galkin, S., Teredesai, M., Nicolay, O.F. and Cangialosi, T.J. (2003). Comparison of measurements made on digital and plaster models. *Am J Orthod and Dentofacial Orthop*; **124:** 101-105.

Sarver, D.M., Proffit, W.R. and Ackerman, J.L. (2000). Diagnosis and treatment planning in orthodontic. In: Orthodontic current principles and techniques, 3 ed (Graber T. M. and Vanarsdall R. L., eds). St. Louis: Mosby, Inc, pp 3-115.

Savastano, N.J. Jr., Firestone, A.R., Beck, F.M. and Vig, K.W. (2003). Validation of the complexity and treatment outcome components of the Index of Complexity, Outcome, and Need (ICON). *Am J Orthod and Dentofacial Orthop*; **124:** 244-248.

Sclare, R. (1945). Orthodontics and the school children: A survey of 680 children. *Br Dent J*; **79:** 278-280.

Sharma, J.N. (2009). Epidemiology of malocclusions and assessment of orthodontic treatment need for the population of eastern Nepal. *World J Orthod*; **10:** 311-316.

Shaw, W.C. (1981). Factors influencing the desire for orthodontic treatment. *Eur J Orthod*; **3:** 151-162.

Shaw, W.C. (1988). Risk benefit appraisal in orthodontics. In orthodontics: evaluations and future. Proceedings of the international conference on the occasion of the 25th Anniversary of the Orthodontic Department of the University of Nijmegen, the Netherlands. October 22-24, 1987. Editors: CFA Moorress and FBGM van der Linden pp. 63-81 [cited by Brook and Shaw, 1989].

Shaw, W.C., Lewis, H.G. and Robertson, N.R.E. (1975). Perception of malocclusion. *Br Dent J*; **138:** 211-216.

Shaw, W.C., Richmond, S., O'Brien, K.D., Brook, P. and Stephens, C.D. (1991). Quality control in orthodontics: Indices of treatment need and treatment standards. *Br Dent J*; **170:** 107-112.

Shivakumar, K.M., Chandu, G.N., Subba Reddy, V.V. and Shafiulla, M.D. (2009). Prevalence of malocclusion and orthodontic treatment needs among middle and high school children of Davangere city, India by using dental aesthetic index. *J Indian Soc Pedod Prev Dent*; **27:** 211-218.

Siegel, M.A. (2002). A Matter of class: Interpreting subdivision in a malocclusion. *Am J Orthod and Dentofacial Orthop*; **122:** 582-586.

Slakter, M.J., Albino J.E., Green L.J. and Lewis E.A. (1980) Validity of an orthodontic treatment priority index to measure need for treatment. *Am J Orthod*; **78:** 421-425.

Snyder R. and Jerrold, L. (2007). Black, white, or gray: Finding commonality on how orthodontists describe the areas between Angle's molar classifications. *Am J Orthod and Dentofacial Orthop*; **132:** 302-306.

So, L.L. and Tang, E.L. (1993). A comparative study using the occlusal index and the index of orthodontic treatment need. *Angle Orthod*; **63:** 57-64.

Souames, M., Bassigny, F., Zenati, N., Riordan, P.J. and Boy-Lefevre, M.L. (2006). Orthodontic treatment need in French schoolchildren: An epidemiological study using the index of orthodontic treatment need. *Eur J Orthod*; **28:** 605-609.

Staley, R.N. (2001). Orthodontic diagnosis and treatment planning. In: Textbook of orthodontics, (Bishara, S. E., eds). WB Saunders Company, Philadelphia, pp 98-112.

Steigman, S. and Weissberg, Y. (1985). Spaced dentition. An epidemiologic study. *Angle Orthod*; **55:** 167-176.

Stenvik, A., Espeland, L., Berset, G.P. and Eriksen, H.M. (1996). Attitudes to malocclusion among 18- and 35-year-old Norwegians. *Community Dent and Oral Epidemiol*; **24:** 390-393.

Stenvik, A., Espeland, L., Linge, O.B. and Linge, L. (1997). Lay attitudes to dental appearance and need for orthodontic treatment. *Eur J Orthod*; **19:** 271-277.

Striffler, D.F., Young, W.O. and Burt, B.A. (1983). Dentistry, dental practise, and the community. 3rd Ed. WB Saunders Company, Philadelphia, pp 75-83.

Summers, C.J. (1971). The occlusal index: A system for identifying and scoring occlusal disorders. *Am J Orthod*; **59:** 552-567.

Tan, T.J. (1996). Profile changes following orthodontic correction of bimaxillary protrusion with a preadjusted edgewise appliance. *Int J Adult Orthod Orthognath Surg*; **11:** 239-251.

Tang, E.L. and So, L.L. (1995). Correlation of orthodontic treatment demand with treatment need assessed using two indices. *Angle Orthod*; **65:** 443-450.

Tang, E.L. (1994). The prevalence of malocclusion amongst Hong Kong male dental students. *Br J Orthod*; **21:** 57-63.

Tang, E.L.K. and Wei, S.H.Y. (1993). Recording and measuring malocclusion: A review of the literature. *Am J Orthod*; **103:** 344-351.

Tarvit**,** D.J. and Freer, T.J. (1998). Assessing malocclusion-the time factor. *Br J Orthod*; **25:** 31-34.

Tausche, E., Luck, O. and Harzer, W. (2004). Prevalence of malocclusions in the early mixed dentition and orthodontic treatment need. *Eur J Orthod*; **26:** 237-244.

Theis, J.E., Huang, G.J., King, G.J. and Omnelld, M.L. (2005). Eligibility for publicly funded orthodontic treatment determined by the handicapping labiolingual deviation index. *Am J Orthod and Dentofacial Orthop*; **128:** 708-715.

Thilander, B. and Myrberg, N. (1973). The prevalence of malocclusion in Swedish schoolchildren. *Scand J Dent Res;* **81:** 12-20.

Thilander, B., Pena, L., Infante, C., Parada, S. and Mayorga, C.D. (2001). Prevalence of malocclusion and orthodontic treatment need in children and adolescents in Bogota, Colombia: An epidemiological study related to different stages of dental development. *Eur J Orthod*; **23:** 153-67.

Thilander, B., Wahlund, S. and Lennartsson, B. (1984). The effect of early interceptive treatment in children with posterior cross-bite. *Eur J Orthod*; **6:** 25-34.

Tod, M.A. and Taverne, A.A. (1997). Prevalence of malocclusion traits in an Australian adult population. *Aust Orthod J;* **15:** 16-22.

Trottman, A. and Elsbach, H.G. (1996). Comparison of malocclusion in preschool black and white children. *Am J Orthod and Dentofacial Orthop*; **110:** 69-72.

Tschill, P., Bacon, W. and Sonko, A. (1997). Malocclusion in the deciduous dentition of Caucasian children. *Eur J Orthod*; **19:** 361-367.

Üçüncü, N. and Ertugay, E. (2001). The use of the Index of Orthodontic Treatment Need (IOTN) in a school population and referred population. *J Orthod*; **28:** 45-52.

Ugur, T., Ciger, S., Aksoy, A. and Telli, A. (1998). An epidemiological survey using the Treatment Priority Index (TPI). *Eur J Orthod;* **20:** 189-193.

United Nations Development Programme (2006). Macroeconomic policies for growth, employment and poverty reduction in Yemen. http://yemencg.org/library/en/psdraft.pdf pp 19-26.

Vahid-Dastjerdi, E., Borzabadi-Farahani, A., Mahdian, M., and Amini, N. (2011). Supernumerary teeth amongst Iranian orthodontic patients. A retrospective radiographic and clinical survey. *Acta Odontol Scand;* **69:** 125-128.

Van Kirk, L.E. and Pennell, E.H. (1959). Assessment of malocclusion in population group. *Am J Orthod*; **45:** 752-758.

Vastardis, H. (2000). The genetics of human tooth agenesis: New discoveries for understanding dental anomalies. *Am J Orthod and Dentofacial Orthop*; **117:** 650-656.

Veenema, A.C., Katsaros, C., Boxum, S.C., Bronkhorst, E.M. and Kuijpers-Jagtman, A.M (2009). Index of complexity, outcome and need scored on plaster and digital models. *Eur J Orthod*; **31:** 281-286.

Wheeler, T.T., Mc Gorray, S.P., Yurkiewicz, L., Keeling, S., Keeling, D. and King, G.J. (1994). Orthodontic treatment demand and need in third and fourth grade schoolchildren. *Am J Orthod and Dentofacial Orthop;* **106:** 22-33.

Williams, A.C. and Stephens, C.D. (1992). A modification to the incisor classification of malocclusion. *Br J Orthod*; **19:** 127-130.

World Health Organisation (1997). Oral health surveys: basic methods-4th edition, Geneva, World Health Organisation.

World Health Organization. (1966). An international methodology for epidemiological studies of oral disease. Manual No 5: epidemiological studies of periodontal disease. First draft. Geneva: World Health Organization.

Yeh, M.S., Koochek, A., Vlaskalic, V., Boyd, R. and Richmond, S. (2000). The relationship of 2 professional occlusal indexes with patients' perceptions of aesthetics, function, speech, and orthodontic treatment need. *Am J Orthod and Dentofacial Orthop*; **118:** 421-428.

Younis, J.W., Vig, K.W.L., Rinchuse, D.J. and Weyant, R.J. (1997). A validation study of three indexes of orthodontic treatment need in the United States. *Community Dent and Oral Epidemiol*; **25:** 358-362.

APPENDICES

Appendix 1: Details of Dental Health Component grades of IOTN

Grade five [very great need for treatment]	
5.i	Impeded eruption of teeth (except for third molars) duo to crowding, displacement, presence of supernumerary teeth, retained deciduous teeth and any pathological cause.
5.h	Extensive hypodontia with restorative implications (more than 1 tooth missing in any quadrant) requiring pre-restorative orthodontic.
5.a	Increased overjet greater than 9 mm.
5.m	Reverse overjet greater than 3.5 mm with reported masticatory and speech difficulties.
5.p	Defects of cleft lip and palate and other craniofacial anomalies.
5.s	Submerged deciduous teeth.
Grade four [great need for treatment]	
4.h	Less extensive hypodontia requiring pre-restorative orthodontics or orthodontic space closure to obviate the need for prosthesis.
4.a	Increased overjet greater than 6 mm but less than or equal 9 mm.
4.b	Reverse overjet greater than 3.5 mm with no masticatory or difficulties.
4.m	Reverse overjet greater 1 mm but less than 3.5 mm with recorded masticatory and speech difficulties.
4.c	Anterior or posterior crossbites with greater than 2 mm discrepancy between retruded contact position and intercuspal position.
4.l	Posterior lingual crossbite with no functional occlusal contact in one or both buccal segments.
4.d	Severe contact point displacements greater than 4 mm.
4.e	Extreme lateral or anterior openbites greater than 4 mm.
4.f	Increased and complete overbite with gingival or palatal trauma.
4.t	Partially erupted teeth, tipped and impacted against adjacent teeth.
4.x	Presence of supernumerary teeth.

Grade three [borderline need for treatment]	
3.a	Increased overjet greater than 3.5 mm but less than or equal to 6 mm with incompetent lips.
3.b	Reverse overjet greater than 1 mm but less than or equal to 3.5 mm.
3.c	Anterior or posterior crossbites with greater than 1 mm but less than or equal to 2 mm discrepancy between retruded contact position and intercuspal position.
3.d	Contact point displacements greater than 2 mm but less than or equal to 4 mm.
3.e	Lateral or anterior openbite greater than 2 mm but less than or equal to 4 mm.
3.f	Deep overbite complete on gingival or palatal tissues but no trauma.
Grade two [little need for treatment]	
2.a	Increased overjet greater than 3.5 mm but less than or equal to 6 mm with competent lips.
2.b	Reverse overjet greater than 0 mm but less than or equal to 1 mm.
2.c	Anterior or posterior crossbite with less than or equal to 1 mm discrepancy between retruded contact position and intercuspal position.
2.d	Contact point displacements greater than 1 mm but less than or equal to 2 mm.
2.e	Anterior or posterior openbites greater than 1 mm but less than or equal to 2 mm.
2.f	Increased overbite greater than or equal to 3.5 mm without gingival contact.
2.g	Pre-normal or post-normal occlusions with no other anomalies (includes up to half a unit discrepancy).
Grade one [not needing for treatment]	
	Extremely minor malocclusion including contact point displacements less than 1 mm.

Appendix 2: Some interpretation for Index of Orthodontic Treatment Need (IOTN)

Buccal occlusion: in a good buccal segment the canines, premolars and molars interdigitate fully regardless of whether a full Class II and III relationship is present. However, if any of these teeth deviate from full interdigitation the DHC grade will be 2.g.

Upper canine	8 mm	
1st premolar	7 mm	Total = 22 mm (impaction < = 18 mm)
2nd premolar	7 mm	

Lower canine	7 mm	
1st premolar	7 mm	Total = 21 mm (impaction < = 17 mm)
2nd premolar	7 mm	

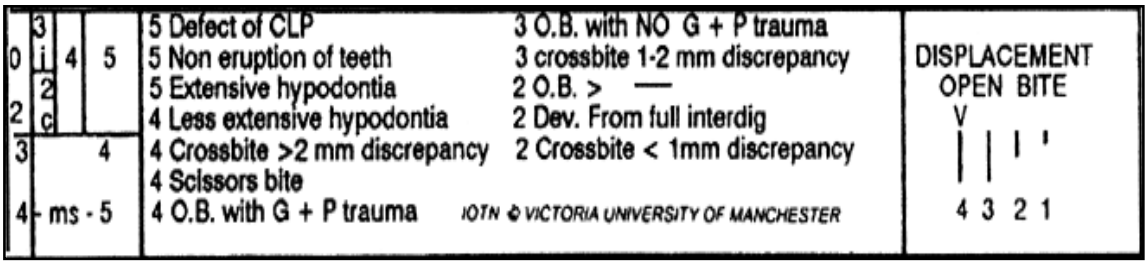
If a tooth has erupted but there is insufficient space in the arch, the displacement score is recorded in terms of contact point displacement. Rotation of teeth: displacements between contact points of rotated teeth are not recorded. If the rotations cause a discrepancy between retruded contact position and intercuspal position, due to cuspal interference, this would then follow similar grading's to crossbite.

Spacing: is not generally recorded in the DHC. If spacing is associated with teeth deviating from the line of the arch, the contact point displacement score is recorded. If teeth have been extracted the residual spacing is not recorded.

Path of closure: discrepancies between intercuspal and retruded contact positions are rated and are recorded in a similar manner to crossbite.

Appendix 3: Dental Health Component (DHC) ruler description

The middle section provides a brief description of occlusal anomalies. The majority are qualitative measurements



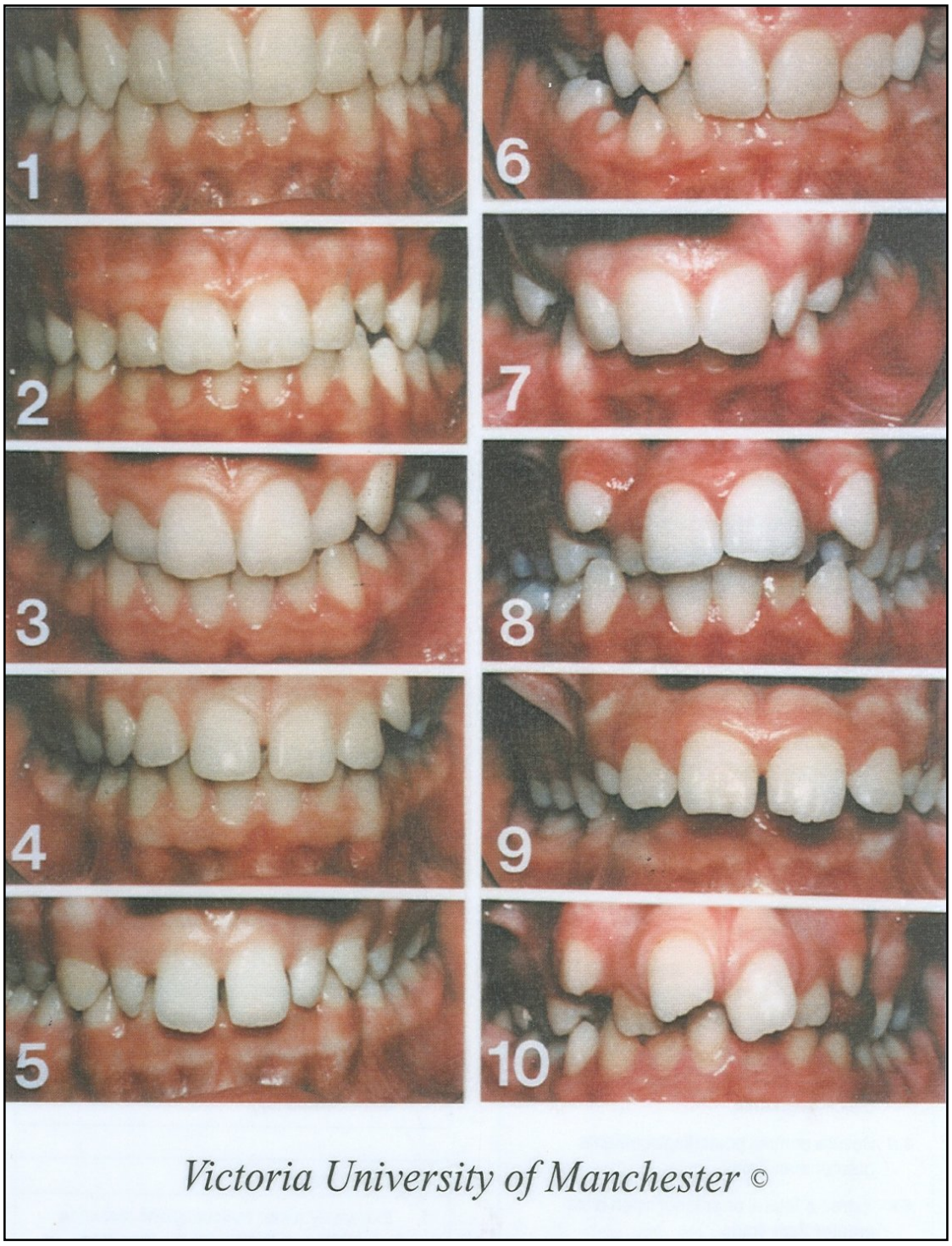
Left section for overjet measurement The upper half records positive and the lower half negative overjet

Abbreviation;

i	-	incompetent lips
c	-	competent lips
O.B	-	gingival and palatal
G + P	-	gingival and palatal
Dev	-	deviation
Interdig	-	Interdigitation

Left section for measurements contact point displacement and openbite

Appendix 4: Aesthetic Component (AC) grades of IOTN



* The scan scale aesthetic photographs was first published by Evans and Shaw (1987)

Appendix 5: Ethics Approval

UNIVERSITI MALAYA
KUALA LUMPUR

UM.D/PD/211

23 February 2007

Dr. Rasheed Abdulsalam Abdullah Al-Maqtari
Children's Dentistry & Orthodontic Department

Via:

Head
Children's Dentistry & Orthodontic Department
Faculty of Dentistry

Sir,

ETHICS APPROVAL

It is a pleasure to inform you that your application for ethics approval on your research titled 'Malocclusion Status and Orthodontic Treatment Need of 14 Year Old Yemeni adolescent; An Epidemiological Study Using (IOTN)' have been granted. Your ethics approval number is DF CD0701/0006(P).

Thank You.

Yours Sincerely,

PROFESOR DR. ROSNAH MOHD ZAIN
Chairperson
Faculty of Dentistry Medical Ethics Committee

c.c.. Dean, Faculty of Dentistry

MS ISO 9001 : 2000 REG. NO. AR 2760

Pejabat Dekan, Fakulti Pergigian, Universiti Malaya, 50603 Kuala Lumpur, Malaysia.
Office of the Dean, Faculty of Dentistry, University of Malaya, 50603 Kuala Lumpur, Malaysia.
Tel: : 603-7967 4812 / 7967 4800 Faks : 603-7956 1607 / 7967 4809

Appendix 6: Letter from supervisor and certified by the Yemeni Embassy in Kuala Lumpur to Thamar University in Yemen

18th December 2006

To: Thamar University
Republic of Yemen

TO WHOM IT MAY CONCERN

Subject: Dr. Rasheed Abdulsalam Abdullah AL- Maqtari

Dr. Rasheed AL-Maqtari is currently enrolled in the in the PhD programme in Orthodontic Dentistry at the Department of Children's Dentistry and Orthdontic , Faculty of Dentistry , University of Malaya , for the academic year 2006 / 2007. Dr. Rasheed needs to travel to Yemen on duty to collect the samples related to his research subject , which is titled (Malocclusion status and Orthodontic treatment need of 14 year old **Yemeni** adolescent , An Epidemiological study , using IOTN)

Thank you

Yours Sincerely

Prof. Dr. Rahimah Abdul Kader
Faculty of Dentistry
University of Malaya

E-Mail : rahimahk@um.edu.my

Department of Community Dentistry
Faculty of Dentistry,
University of Malaya,
50603 Kuala Lumpur

Appendix 7: Letter from Vice-Rector, Postgraduate Studies & Scientific Research in Thamar University to Yemeni Director of Education [in English]

REPUBLIC OF YEMEN
THAMAR UNIVERSITY
University Vice Rector for Postgraduate Studies & Scientific Research.

To : Office of Education , the Capital Sub-Governorate Division
Dear Director

With faithful greetings. Thamar University is sending to you this message with regard to **Dr. Rasheed Abdulsalam Al-Maqtari** , a postgraduate student dispatched by the university to University of Malaya where he is pursuing studies for Doctorate (Ph.D) degree in dentistry majoring **Orthodontics**. Presently he has come into phase for setting up his dissertation associated with the degree.

We would request you to address principals of schools in your sector to receive him as a researcher in an evaluating task. He is going to detect oral and dental health conditions among a sample of pupils at 14- years without being subjected to treatment. Detection will also cover further samples collected nationwide. Noteworthily. Your governorate is going to be namely mentioned in the final research.

Thanks for your cooperation

REPUBLIC OF YEMEN University of Thamar Vice Rector for Postgraduate Studies & Scientific Research

Professor Dr./ Ahmad Abdulla Salih
Vice-Rector for Postgraduate Studies & Scientific Research.

Notes
Observed in the Arabic origin copy of this letter two official annotations signed by the addressee and his associates addressed to educational zones' directors, and principals to provide access and support to ease the mission of the concerned researcher. Similar messages has been sent to educational offices in nine governorates.

Appendix 8: letter from Vice-Rector, Postgraduate Studies & Scientific Research in Thamar University to Yemeni Director of Education [in Arabic]

REPUBLIC OF YEMEN
THAMAR UNIVERSITY
University Vice - Rector
For Postgraduate
Studies & Scientific Research
NO: .....
Date: .....

بسم الله الرحمن الرحيم

الجمهورية اليمنية
جامعة ذمار
نائب رئيس الجامعة
للدراسات العليا والبحث العلمي
الرقم: .....
التاريخ: .....

جامعة ذمار
عمادة الدراسات العليا
والبحث العلمي
تاريخ ٢٠٠٨/٤/٨ م المرفقات

الأخ الأستاذ/ مدير مكتب التربية – محافظة شبوة المحترم

تهديكم جامعة ذمار أطيب تحياتها . . .

وتود إحاطتكم علماً بأن الدكتور/ **رشيد عبد السلام المقطري** – موفد الجامعة في ماليزيا لتحضير درجة الدكتوراه تخصص (**تقويم أسنان**) والمذكور في مرحلة إعداد الرسالة العلمية .

وعليه: نرجو منكم التوجيه إلى مدراء المدارس لتسهيل مهمته لتقييم الحالة الصحية للفم والأسنان لطلاب المدارس عمر (**14 – 15 سنة**) دون إجراء أي علاج لهم لتشخيص أمراض الأسنان والفم على مستوى الجمهورية .

علماً بأنه سوف يتم ضم اسم محافظتكم كأحد المصادر الخاصة بالبحث .

شاكرين حسن تعاونكم ؛؛؛

نائب رئيس الجامعة للدراسات
العليا والبحث العلمي
أ.د/ أحمد عبده صالح

جامعة ذمار
THAMAR UNIVERSITY
عمادة الدراسات العليا والبحث العلمي

P.O. Box (87246) Tel: 509575 - Fax: 509575 — ص.ب (87246) تلفون: 509575 - فاكس 509575

Appendix 9: Protocol and permission latter to participating schools' headmasters [in English]

In The Name of God, Most Gracious, Most Merciful

To: The headmaster _____.

I would like to inform you that and conducting a field research of malocclusion statues and orthodontic treatment need of 14 year old Yemeni students. Therefore, I would like your approval to our request to examine the students without giving any medication under the school's supervision.

This study useful for building a database in Yemen for future orthodontic treatment needs plan. Moreover, your school will be one of the sample sources pertaining to this research.

Thanking you in advance.

Dr: Rasheed Abdulsalam Al-Maqtari

Appendix 10: Protocol and permission latter to participating schools' headmasters [in Arabic]

بسم الله الرحمن الرحيم

الاستاذ مدير مدرسه _____ المحترم

تحيه طيبه و بعد

نحيطكم علما باننا نقوم باجراء بحث ميداني للتقيم الاختلالات بالاطباق والاحتياجات العلاجيه للتقويم الاسنان للفئه العمريه 14 سنه على مستوى اليمن. لذا نرجو التكرم منكم بالموافقه على طلبنا في فحص طلاب مدرستكم دون اجراء اي علاج لهم تحت اشراف ادارة المدرسة . حيث ان الدراسه مفيده للحصول على قاعده بيانات لعلاج تقويم الاسنان واحتياجاته في المستقبل .

هذه و ستضم مدرستكم كأحد المصادر لعينات الخاصه للبحث.

ولكم جزيل الشكر

د. رشيد عبد السلام المقطري

Appendix 11: Participant consent letter for photograph [in English]

PERMISSION FOR ORAL EXAMINATION AND PHOTOGRAPH RELEASE

Participant name: _____

I hereby give permission to Dr. Rasheed Abdulsalam to examine and take photograph to illustrate in his research. I further authorise the use of the photograph for teaching purposes or to illustrate scientific papers or lectures at any time hereafter without inspection or approval on my part. The photograph can be use in scientific purposes only.

I hereby consent to all the above procedures.

_____

(Participant Signature)

Date.

Appendix 12: Participant consent letter for photograph [in Arabic]

اقرار بموافقة الفحص و التصوير

الاسم :_____

انا الموقع ادناة أمنح هذا التصريح للدكتور رشيد عبد السلام للقيام بفحص اسناني واستخدام صورتي في بحثه. كما أني أذن لة باستخدام الصورة لأغراض التدريس أو نشر ورقة علمية أو محاضرات في أي وقت دون الرجوع لي. وليس عندي اي مانع من استخدام صورتي في الأغراض العلمية فقط.

وهدة أقرار مني بالموافقة على جميع الإجراءات المذكورة أعلاه

التوقيع : _____

التاريخ .

Appendix 13: Clinical examination form

CLINICAL EXAMINATION FORM

I. General and Personal Information:

Date. ____ Ser. No. ____

School Name ____ Governorate ____

Location. ____ 1= Urban 2= Rural Gender. ____ 1= Male 2= Female

Name. ____ Birth date. ____

II. Occlusal Traits Based on FDI/WHO Objective Method:

A. Dental discrepancies:

I. Impacted teeth.
C. Congenital absent teeth.
EX. Missing teeth (extraction/trauma).
S. Supernumerary teeth.
M. Malformation
R. Retained deciduous teeth.

	C1	L1	C	1PM	2PM	1M	2M
Maxilla							
Mandible							

	A	B	C	D	E
Maxilla					
Mandible					

B. Space discrepancies:

1) Maxillary Diastema ____
0= None
1= 2 mm and more
X= Extracted incisors

2) Crowding and Spacing.
0= None
1= less than 2 mm
2= 2 mm and more
maxilla ____
mandible ____

C. Anterio-posterior occlusal relationship:

1) Molar relationship.

Right		Left	
Class I		Class I	
Class II		Class II	
Class III		Class III	

Codes of Class II or Class III Units:

1= ¼ Unit
2= ½ Unit
3= ¾ Unit
4= Full Unit
x= extracted molar

2) Overjet and anterior crossbite.

i- Maxillary overjet ☐

0= (< 6 mm)
1= (6 to < 9 mm)
2= (≥ 9 mm)

ii- Reverse overjet ☐

0= None
1= Present

iii –Anterior crossbite. ☐

0= None
1= One tooth
2= Two teeth
3= Three teeth

D. Vertical occlusion relationship:

1) Overbite ☐

0= (0 to < 2/3 overlap)
1= (2/3 to < 3/3 overlap)
2= (3/3 and more overlap)

2) Anterior openbite ☐

0= None
1= Present

3) Posterior openbite. ☐

0= None
1= Present

E. Transversal occlusion relationship:

1) Posterior crossbite Right ☐ Left ☐

2) Scissor bite Right ☐ Right ☐

0= None
1= Present

III. Extra occlusal traits observed

1) Incisor Classification:

Class I ☐ Class II div1 ☐ div2 ☐ Class III ☐

2) Canine relationship:

Right	
Class I	
Class II	
Class III	

Left	
Class I	
Class II	
Class III	

Codes of Class II or III Units:

1= ¼ Unit
2= ½ Unit
3= ¾ Unit
4= Full Unit
x= extracted canine

3) Comments:

IV. Dental Health Component of IOTN:

1) Impeded eruption. 5i ☐ Reason ☐ 1)crowding 2)displacement 3)supernumerary 4)retained deciduous 5)pathological

2) Hypodontia. 5h ☐ severe

4h ☐ mild

3) Increased overjet.

5a ☐ more than 9 mm.

4a ☐ 6 - 9 mm.

3a ☐ 3.5 - 6 mm (incompetent lip).

2a ☐ 3.5 - 6 mm (competent lip).

4) Reverse overjet.

5m ☐ >3.5mm with masticatory/ speech difficulty.

4b ☐ >3.5mm with no masticatory/ speech difficulty

4m ☐ >1mm<3.5 with masticatory/ speech difficulty

3b ☐ > 1mm ≤ 3.5 mm.

2b ☐ > 0 mm ≤ 1 mm.

5) Clift lip and palate and craniofacial anomalies. 5P ☐

6) Submerged deciduous teeth. 5S ☐

7) Crossbite (Anterior or Posterior).

4C ☐ > 2 mm discrepancy

3C ☐ > 1 mm but ≤ 2 mm

2C ☐ ≤ 1 mm

8) Posterior lingual crossbite. 4L ☐ with no functional occlusal contact

9) Contact point displacement.

4d ☐ > 4 mm

3d ☐ > 2 mm but ≤ 4 mm

2d ☐ >1 mm but ≤ 2 mm

10) Openbite (Anterior or Posterior).

4e ☐ > 4 mm

3e ☐ > 2 mm but ≤ 4 mm

2e ☐ >1 mm but ≤ 2 mm

11) Overbite.

4f ☐ increased and complete with gingival trauma

3f ☐ complete but no trauma

2f ☐ more than or equal to 3.5mm without gingival contact

12) Partially erupted teeth. 4t ☐

13) Supernumerary. 4x ☐

14) Occlusion (Pre/Post normal). 2g ☐ No other anomalies (1/2 unit discrepancy)

15) DHC of IOTN.

1	2	3	4	5
☐	☐	☐	☐	☐

V. Aesthetic Component of IOTN:

1) Examiner evaluation.

1	2	3	4	5	6	7	8	9	10

2) Subjects evaluation.

1	2	3	4	5	6	7	8	9	10

Appendix 14: Distribution of dental discrepancies of pilot study

Dental discrepancies	Subjects (N= 60)	
	n	%
Impacted teeth as clinically observed	4	6.7
Congenitally missing teeth as observed clinically	0	0
Missing (extraction/ trauma)	0	0
Supernumerary teeth	0	0
Malformation	0	0
Partially erupted teeth	7	11.7
Retained deciduous teeth	4	6.7

Appendix 15: Distribution of space discrepancies of pilot study

Space discrepancies			Subjects	
			n	%
Maxilla	Crowding	≥ 2 mm	6	10.0
		< 2 mm	14	23.3
	Spacing	≥ 2 mm	2	3.3
		< 2 mm	3	5.0
	Diastema ≥ 2 mm		2	3.3
	No space discrepancies		33	55.0
	Total		60	100
Mandible	Crowding	≥ 2 mm	17	28.3
		< 2 mm	12	20.0
	Spacing	≥ 2 mm	0	0
		< 2 mm	1	1.7
	No space discrepancies		30	50.0
	Total		60	100

Appendix 16: Distribution of anterio-posterior occlusal relationship of pilot study

Anterio-posterior occlusion relationship		Subjects	
		n	%
Reverse overjet		3	5.0
Anterior crossbite		0	0
Bimaxillary protrusion		5	8.3
Increase overjet	≥ 6 mm	10	16.7
Acceptable overjet	0 to < 6 mm	42	70.0
Total		60	100

Appendix 17: Distribution of vertical occlusal relationship of pilot study

Vertical occlusion relationship		Subjects	
		n	%
Anterior openbite		1	1.7
Posterior openbite		0	0
Deep overbite	3/3 overlap and over	3	5.0
	2/3 to < 3/3 overlap	14	23.3
Acceptable overbite	< 2/3 overlap	42	70.0
Total		60	100

Appendix 18: Distribution of molar and canine relationships of pilot study

Angle Classification Classes	Molar relationship right		Molar relationship left		Canine relationship right		Canine relationship left	
	n	%	*n*	%	*n*	%	*n*	%
Class I	34	56.7	34	56.7	29	48.3	31	51.7
Class II ¼ unit	16	26.7	17	28.3	14	23.3	17	28.3
Class II ½ unit	5	8.3	4	6.7	9	15	5	8.3
Class II ¾ unit	1	1.7	0	0	3	5.0	2	3.3
Full unit Class II	0	0	0	0	0	0	0	0
Class III ¼ unit	2	3.3	3	5.0	3	5.0	3	5.0
Class III ½ unit	2	3.3	2	3.3	2	3.3	2	3.3
Class III ¾ unit	0	0	0	0	0	0	0	0
Full unit Class III	0	0	0	0	0	0	0	0
Total	60	100	60	100	60	100	60	100

Appendix 19: Treatment need according to Dental Health Component of IOTN – results of pilot study

Grades of DHC	Grade meaning	n	%
5	Very great treatment need	25	41.6
4	Great treatment need	10	16.7
3	Borderline treatment need	12	20
2	Little treatment need	10	16.7
1	No treatment need	3	5
Total	-	60	100

Appendix 20: Treatment need according to Aesthetic Component of IOTN- results of pilot study

Grades of AC	Categorisation of treatment needs	Examiner assessment		Subjects assessment	
		n	*%*	*n*	*%*
Grade 10	Definite need	0	0	0	0
Grade 9		3	5.0	2	3.3
Grade 8		2	3.3	1	1.7
Grade 7	Borderline need treatment	5	8.3	3	5.0
Grade 6		3	5.0	2	3.3
Grade 5		5	8.3	4	6.7
Grade 4	No need	7	11.7	1	1.7
Grade 3		9	15.0	11	18.3
Grade 2		4	6.7	10	16.6
Grade 1		22	36.7	26	43.3
Total	-	60	100	60	100

Appendix 21: Distribution of occlusal traits of IOTN grades among the sample

Occlusal traits of IOTN grades	Subject number in grades	Percentage in grades
5.i Impeded eruption	137	48.6
5.h Extensive hypodontia	23	8.2
5.a Increased over jet > 9 mm	89	31.5
5.m Reverse over jet > 3.5 mm with speech difficulties	5	1.7
5.p Cleft lip and palate	11	4.0
5.s Submerged	17	6.0
Total of Grade 5	282	100
4.h Less hypodontia	29	8.1
4.a Increased overjet > 6 mm to ≤ 9 mm	108	30.0
4.b Reverse overjet > 3.5 mm no speech difficulties	2	0.5
4.m Reverse overjet > 1 mm < 3.5 mm with speech difficulties	3	0.8
4.c Crossbites > 2 mm	22	6.1
4.l Lingual crossbite	11	3.1
4.d Displacements > 4 mm	141	39.1
4.e Openbites > 4 mm	8	2.2
4.f Complete overbite with gingival trauma	0	0.0
4.t Partially erupted	27	7.5
4.x Supernumerary teeth	9	2.5
Total of Grade 4	360	100
3.a Increased overjet > 3.5 mm to ≤ 6 mm, incompetent	148	32.2
3.b Reverse overjet > 1 mm to ≤ 3.5 mm	4	0.9
3.c Crossbites > 1 mm to ≤ 2 mm	25	5.9
3.d Displacements > 2 mm to ≤ 4 mm	200	47.6
3.e Openbites >2 mm to ≤ 4 mm	19	4.5
3.f Complete overbite no gingival trauma	24	5.7
Total of Grade 3	420	100
2.a Increased overjet > 3.5 mm to ≤ 6 mm	127	22.1
2.b Reverse overjet > 0 mm to ≤ 1 mm	11	1.9
2.c Crossbites ≤ 1 mm	18	3.1
2.d Displacements > 1 mm to ≤ 2 mm	269	46.8
2.e Openbites > 1 mm to ≤ 2 mm	52	9.1
2.f Increased overbite ≥ 3.5 mm no gingival trauma	67	11.7
2.g Pre-post normal occlusions	30	5.2
Total of Grade 2	574	100
1. Extremely minor malocclusions Grade 1	764	31.8

Appendix 22: Distribution of occlusal traits of IOTN grades by zones

Occlusal traits of IOTN grades	Zones										Total of grades	
	North		South		Middle		East		West			
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
5.i	33	57.8	32	46.4	28	45.2	23	46.9	21	46.6	137	48.6
5.h	3	5.3	5	7.2	7	11.3	4	8.2	4	8.8	28	8.2
5.a	18	31.6	23	33.3	20	32.3	16	32.6	12	26.6	89	31.5
5.m	1	1.7	0	0.0	0	0.0	1	2.0	3	6.6	5	1.7
5.p	0	0.0	4	5.8	2	3.2	2	4.1	3	6.6	11	4.0
5.s	2	3.5	5	7.2	5	8.1	3	6.1	2	4.4	17	6.0
Total of Grade 5	57	100	69	100	62	100	49	100	45	100	282	100
4.h	8	8.5	5	9.6	4	5.9	5	5.1	7	14.3	29	8.1
4.a	24	25.5	26	50.0	22	32.8	21	21.4	15	30.6	108	30.0
4.b	1	1.1	0	0.0	0	0.0	0	0.0	1	2.0	2	0.5
4.m	0	0.0	1	1.9	0	0.0	1	1.0	1	2.0	3	0.8
4.c	7	7.4	1	1.9	4	5.9	9	9.2	1	2.0	22	6.1
4.l	2	2.1	1	1.9	4	5.9	3	3.1	1	2.0	11	3.1
4.d	42	44.6	14	26.9	19	28.4	48	48.9	18	36.7	141	39.1
4.e	2	2.1	0	0.0	3	4.5	1	1.0	2	4.1	8	2.2
4.f	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4.t	6	6.4	2	3.8	10	14.9	7	7.1	2	4.1	27	7.5
4.x	2	2.1	2	3.8	1	1.5	3	3.1	1	2.0	9	2.5
Total of Grade 4	94	100	52	100	67	100	98	100	49	100	360	100
3.a	23	26.7	26	35.1	30	30.6	38	40.0	31	46.2	148	32.2
3.b	1	1.2	0	0.0	1	1.0	2	2.1	0	0.0	4	0.9
3.c	10	11.6	5	6.7	5	5.1	2	2.1	3	4.5	25	5.9
3.d	42	48.8	38	51.3	51	52.0	42	44.2	27	40.3	200	47.6
3.e	2	2.3	2	2.7	6	6.1	8	8.4	1	1.5	19	4.5
3.f	8	9.3	3	4.1	5	5.1	3	3.1	5	7.5	24	5.7
Total of Grade 3	86	100	74	100	98	100	95	100	67	100	420	100
2.a	29	30.8	32	24.2	19	20.8	23	18.8	24	17.7	127	22.1
2.b	1	1.1	2	1.5	2	2.2	2	1.6	4	2.9	11	1.9
2.c	4	4.2	6	4.5	6	6.6	1	0.8	1	0.7	18	3.1
2.d	39	41.4	59	44.7	44	48.3	58	47.5	69	51.1	269	46.8
2.e	6	6.3	12	9.1	2	2.2	18	14.7	14	10.4	52	9.1
2.f	8	8.5	16	12.1	17	18.6	12	9.8	14	10.4	67	11.7
2.g	7	7.4	5	3.7	1	1.1	8	6.5	9	6.6	30	5.2
Total of Grade 2	94	100	132	100	91	100	122	100	135	100	574	100
Grade 1	149	100	153	100	162	100	116	100	184	100	764	100
All sample	480		480		480		480		480		2400	

Appendix 23: Distribution of occlusal traits of IOTN grades by location and gender

Occlusal traits of IOTN grades	Location				Gender				Total of grades	
	Urban		Rural		Male		Female			
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
5.i	73	52.1	64	45.1	74	52.1	63	45.0	137	48.6
5.h	13	9.3	10	7.0	11	7.7	12	8.6	28	8.2
5.a	43	30.7	46	32.3	39	27.4	50	35.7	89	31.5
5.m	0	0.0	5	3.5	3	2.1	2	1.4	5	1.7
5.p	6	4.3	5	3.5	5	3.5	6	4.3	11	4.0
5.s	5	3.6	12	8.5	10	7.0	7	5.0	17	6.0
Total of Grade 5	140	100	142	100	142	100	140	100	282	100
4.h	17	8.9	12	7.1	16	8.6	13	7.5	29	8.1
4.a	61	32.1	47	27.6	65	34.9	43	24.5	108	30
4.b	1	0.5	1	0.6	2	1.1	0	0.0	2	0.5
4.m	2	1.0	1	0.6	3	1.6	0	0.0	3	0.8
4.c	8	4.2	14	8.2	7	3.8	15	8.6	22	6.1
4.l	5	2.6	6	3.5	6	3.2	5	2.9	11	3.1
4.d	72	37.9	69	40.6	66	35.5	75	43.1	141	39.1
4.e	3	1.6	5	2.9	4	2.2	4	2.3	8	2.2
4.f	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4.t	18	9.5	9	2.3	12	6.5	15	8.6	27	7.5
4.x	3	1.6	6	3.5	5	2.7	4	2.3	9	2.5
Total of Grade 4	190	100	170	100	186	100	174	100	360	100
3.a	65	33.3	83	36.8	77	32.5	71	38.8	148	32.2
3.b	0	0.0	4	1.7	3	1.3	1	0.5	4	0.9
3.c	13	6.6	12	5.3	16	6.7	9	4.9	25	5.9
3.d	97	49.7	103	45.7	117	49.4	83	45.3	200	47.6
3.e	10	5.1	9	4.0	12	5.1	7	3.8	19	4.5
3.f	10	5.1	14	6.2	12	5.1	12	6.5	24	5.7
Total of Grade 3	195	100	225	100	237	100	183	100	420	100
2.a	71	24.9	56	19.3	70	27.2	57	17.9	127	22.1
2.b	2	0.7	9	3.1	5	1.9	6	1.9	11	1.9
2.c	7	2.5	11	3.8	6	2.3	12	3.8	18	3.1
2.d	127	44.5	142	49.1	108	42	161	50.7	269	46.8
2.e	27	9.5	25	8.6	19	7.4	33	10.4	52	9.1
2.f	31	10.8	36	12.5	36	14	31	9.7	67	11.7
2.g	20	7.0	10	3.4	13	5.1	17	5.4	30	5.2
Total of Grade 2	285	100	289	100	257	100	317	100	574	100
Grade 1	390	100	374	100	377	100	387	100	764	100
All sample	1200		1200		1200		1200		2400	

Appendix 24: Correlation of normative and subjects perceived orthodontic treatment need categories

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	.326	.017	15.055	.000
N of Valid Cases		2400			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Appendix 25: Correlation of examiner and subjects according to Aesthetic Component treatment need categories

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	.627	.013	34.943	.000
N of Valid Cases		2400			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Appendix 26: Letter from Yemen Dental Association regarding to the number of orthodontists in Yemen

Republic of Yemen

Yemen Dental Association

الجمهورية اليمنية

نقابة أطباء الأسنان اليمنيين

النشـــاط العلمي

No. : ..... الرقم : .....

Date : ..... التاريخ : .....

To whom it may concern

That the number of association orthodontist members are (25) divided for Government as following :

In Sana'a Gov	(15)
In Aden	(3)
In Hodeida	(1)
In Taiz	(2)
In Ibb	(2)
In THamar	(2)

Head of Y.D.A

Dr. Moh Salem

طباء الأسنان اليمنيين YEMEN DENTAL ASSOCIATION

Tel.: 414891 / 415903 - P.O.Box : 4015

ت: ٤١٥٩٠٣ / ٤١٤٨٩٧ - فاكس: ٤١٤٨٩٦ - ص.ب: ٤٠١٥

Appendix 27: Crosstabulation of orthodontic treatment need categories with Incisor Classification Classes

		Treatment Need Categories by DHC						Total	
		No need		Borderline need		Definite need			
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Incisor Classification	Class I	985	41.0	136	5.7	258	10.8	1379	57.5
	Class II div 1	210	8.5	209	8.7	255	10.6	668	27.8
	Class II div 2	6	0.3	13	0.5	9	0.4	28	1.2
	Class III	143	6.0	62	2.6	120	5.0	325	13.5
Total		1338	55.8	420	17.5	642	26.8	2400	100