HARD AND SOFT TISSUE CHANGES FOLLOWING TWO MODES OF RETENTION MANAGEMENT AFTER TWIN BLOCK THERAPY: A RETROSPECTIVE CEPHALOMETRIC STUDY

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by

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LIST OF ABBREVIATIONS

SD	Standard deviation
IQR	Interquartile Range
ICC	Intra-class correlation coefficient
MRI	Magnetic Resonance Imaging
OSLS	Optical Surface Laser Scanning
MARA	Mandibular Anterior Repositioning Appliance
AMDI	Advanced Medical & Dental Institute
PPSG	School of Dental Sciences
USM	Universiti Sains Malaysia

PERUBAHAN TISU KERAS DAN LEMBUT SELEPAS TERAPI BLOK BERKEMBAR DENGAN DUA MOD PENGURUSAN RETENSI BERBEZA: KAJIAN SEFALOMETRIK RETROSPEKTIF

ABSTRAK

Kajian sefalometrik retrospektif dijalankan di Institut Perubatan & Pergigian Termaju (IPPT), Universiti Sains Malaysia (USM), untuk menilai perubahan tisu lembut dan keras yang berlaku pada dua kumpulan pesakit yang menerima dua rawatan ulangan yang berbeza selepas terapi blok berkembar. Rekod radiografi yang digunakan adalah terdiri daripada daripada pesakit etnik Melayu, berumur antara 10 hingga 15 tahun. Pesakit-pesakit ini didiagnosis mengalami Kelas II Divisi 1 overjet 5 mm atau lebih atau pola skeletal Kelas II dengan sudut ANB 5^{o} atau lebih dan dirawat dengan alat blok berkembar. Rekod 26 pesakit telah dikumpul dan dibahagikan kepada dua kumpulan. Kumpulan (A) terdiri daripada imej radiografi subjek yang menerima aplians ortodontik tetap dengan serta-merta selepas terapi blok berkembar dan kumpulan (B) adalah imej sefalometrik subjek yang menerima aplians alat ortodontik tetap selepas tempoh retensi 3 bulan selepas terapi blok berkembar. Imej radiografi sefalometric lateral dari pangkalan data dikelompokkan kepada, (T1): sebelum terapi blok berkembar, (T2): selepas selesai terapi blok berkembar dan (T3): selepas 6 bulan dipasang aplians tetap. Beberapa analisis sefalometrik digunakan termasuk Holdaway, Burstone, Pancherz, dan Steiner untuk menilai perubahan tisu lembut dan tisu keras, samada dari segi skeletal, dental, atau dento-alveolus. Ujian Mann-Whitney dilakukan untuk membandingkan perbezaan pra-rawatan (T1) kumpulan pesakit A dan B. Ujian Wilcoxon digunakan untuk mengesan perubahan yang berlaku mengikut masa di dalam satu kumpulan. Perubahan antara kumpulan A dan B dalam (T2) dan (T3) telah

dibandingkan dengan ujian Mann-Whitney. Ujian pangkat bertanda Wilcoxon menunjukkan perbezaan yang signifikan bagi kumpulan (A) antara peringkat T2 dan T3 pada tisu lembut, rangka, gigi, dan dento-alveolus. Bagi kumpulan (B), perbezaan didapati pada kedudukan kondil, tisu lembut, dan molar pertama pada tulang alveolus. Apabila membandingkan perbezaan menggunakan ujian Mann-Whitney didapati tidak terdapat perbezaan statistik antara kumpulan-kumpulan yang menunjukkan pemboleh ubah linear atau angular tidak berubah melebihi 2.5 mm atau 2.5^{o}. Keputusan menunjukkan bahawa tempoh pengekalan 3 bulan tidak memberi sebarang manfaat jika dibandingkan dengan perubahan yang dilihat pada pesakit yang menerima aplians ortodontik tetap dengan serta-merta.

HARD AND SOFT TISSUE CHANGES FOLLOWING TWO MODES OF RETENTION MANAGEMENT AFTER TWIN BLOCK THERAPY: A RETROSPECTIVE CEPHALOMETRIC STUDY

ABSTRACT

A retrospective cephalometric study was conducted in the Advanced Medical & Dental Institute (AMDI), Universiti Sains Malaysia (USM), to assess the soft and hard tissues changes that occur in two sets of patients receiving two different relapse management after Twin block therapy. The radiographic records consisted of Malay ethnicity patients age ranged between 10 and 15 years. Patients were diagnosed as Class II Division 1 malocclusion with overjet of 5 mm or greater or Class II skeletal pattern of ANB angle of 5^{o} or greater and were treated with the Twin block appliance. The records of 26 patients were found and were divided into two groups. Group (A) is those radiographs from subjects who received fixed orthodontic appliance immediately after the Twin block therapy and group (B) is those radiographs from subjects who received fixed orthodontic appliance after 3 months retention period after Twin block therapy. Lateral cephalometric radiographs from the database were grouped into, (T1): before Twin block therapy, (T2): after Twin block therapy completion, and (T3): after 6 months of fixed appliance placement. Several cephalometric analyses were used including Holdaway, Burstone, Pancherz, and Steiner to assess soft tissue changes and hard tissue changes weather that be skeletal, dental, or dento-alveolar. Mann-Whitney test to compare pre-treatment (T1) measurements of groups A and B patients. Wilcoxon signed-rank test was used to detect changes occurring through time within the groups. Changes between group A and B in (T2) and (T3) were compared using Mann-Whitney test. Wilcoxon signed-

rank test showed significant differences were found in group (A) between T2 and T3 stages which included soft tissues, skeletal, dental, and dento-alveolar. In group (B) significance was found in the in the condyle position, soft tissue pogonion position, and the position of the upper first molar within the alveolar bone. When comparing, the differences using Mann-Whitney test it was found that there is no statistical difference between the groups indicating that linear or angular variables had not changed beyond 2.5 mm or 2.5^o. The results suggest that the 3 months retention is not beneficial when compared to the changes observed in the immediate fixed appliance stage.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Orthodontic is a field that combines art and science. It is indispensable to connect to the beauty of a human face that holds an aesthetic attractive smile. Beauty is a quality best expressed in balanced facial features. The true challenge of this field lies within pursuing the perfection of balancing between arrangement of dentition and their function. Success of any orthodontic treatment relies on that balance to achieve harmonious aesthetic results. As our knowledge expands through countless advancement in medical research, debates, and exchange of theories, it leads us forward to a faster and more sustainable orthodontic treatment.

Functional appliances are orthodontic appliances that utilise the forces generated by the muscles to accomplish skeletal and dental changes through growth modification. The Twin block appliance is a functional appliance that was developed by William J. Clark (Clark, 1982). The Twin block is used mainly to correct skeletal Class II and Class III malocclusion both of which are considered prevalent types of malocclusion in several parts of the world.

One of the controversial issues of the Twin block is the relapse management during the transition period between the end of the Twin block therapy and the fixed appliance stage. This transition period is handled differently either by placing the fixed appliance immediately after the end of the Twin block stage or after three months retention period between functional and fixed appliance phases (Fleming et al., 2007). The retention management consists of three months time and includes several options such as wearing the Twin block partially during night time only, modifying the Twin block appliance by adding an anterior bite plane, or adjusting the appliance to allow partial bonding with the fixed appliance if the fixed appliance has already been bonded after the completion of the Twin block stage. While the transition phase may be used as a retention phase it comes with a certain disadvantage of increasing treatment time which leads to a decrease in patient compliance and possibly discontinuation of the orthodontic treatment (Hsieh et al., 2005).

Placement of teeth according to the accepted hard tissue cephalometric criteria does not necessarily ensure that the overlying soft tissue will drape in harmony for a variety of reasons. The skeletal and dento-alveolar changes produced by functional appliances are well documented by researchers (Mills and McCulloch, 2000, Gill and Lee, 2005, Jena et al., 2006, Thiruvenkatachari et al., 2010, Saikoski et al., 2014, Ehsani et al., 2015).

There has been a great focus on cephalometric soft tissue changes following Twin block therapy in the past few years. These studies indicate that soft tissue changes are closely related to the bone changes produced by the Twin block appliance and that the Twin block induces favourable soft tissue changes either when compared to normal growth or when compared with other functional appliances (McDonagh et al., 2001, Quintão et al., 2006, Sumitra, 2006, Baysal and Uysal, 2011).

Hard tissues may remain stable after the completion of Twin block therapy without using any retention during the transition period of three months (Gill and Lee, 2005). However, similar response may not be achieved in regard to the soft tissue perspective. In a parallel study, the soft tissue changes attained by Twin block treatment may not be stable without a proper retaining period to preserve the induced changes and therefore relapsed (Sharma and Lee, 2005). A previous study was carried out to evaluate the dento-alveolar and skeletal changes that takes place in patients who had undergone fixed appliance treatment either immediately after Twin block therapy or after three months of retention after Twin block therapy (Hussain, 2011). The results showed that there is no significant hard tissue relapse between the two groups except in a few aspects. However, the study does not address the soft tissue changes in these two types of relapse management neither does it show if any relapse has occurred in hard or soft tissues after the completion of the fixed appliance.

To this day it is not clear weather using the transition period as a retention period between functional and fixed appliance phases would have any effect on the soft tissue relapse. Additionally, the subject of the stability of soft tissue changes induced by the Twin block in the long term after completing the orthodontic treatment remains an open question.

1.2 Problem statement & study rationale

To our knowledge, comparison of the effects of hard and soft tissues changes after six months using two modes of Twin block relapse management in Malay ethnic population had not been carried out. It is also unclear if the hard and soft tissue changes are stable after six months of Twin block therapy completion. We would like to contribute to this growing field of knowledge following the footsteps of previous researchers by producing useful data through cephalometric analysis of the soft tissue changes in response to two modes of relapse management using Twin block appliance. We hope the data we provide will be useful for future researchers.

1.3 Objective

1.3.1 General objective:

The aim of the study is to evaluate the hard and soft tissue changes after six months of Twin block therapy completion. The cephalometric changes are analysed and compared between two groups of patients who had received two different relapse management during the three months transition period after the completion of the Twin block therapy.

1.3.2 Specific objectives:

1- To assess the hard and soft tissue changes after six months of Twin block therapy completion in patients who did not receive retention.
2- To assess the hard and soft tissue changes after six months of Twin block therapy completion in patients who received three months retention.
3- To compare the hard and soft tissue changes after six months of Twin block therapy completion between immediate and delayed placement of fixed appliance.

1.3.3 Research null hypothesis

1- No significant change takes place in hard or soft tissue after six months of Twin block therapy completion in patients who did not receive retention.

2- No significant change takes place in hard or soft tissue after six months of Twin block therapy completion in patients who received retention for three months.

3- No significant change takes place in hard or soft tissue after six months of Twin block therapy completion between patients who had immediate or delayed placement of fixed appliance after.

CHAPTER 2

LITERATURE REVIEW

Orthodontics is defined as the branch of dentistry concerned with growth and development of the face, dentition, and correcting or preventing occlusal anomalies (Houston et al., 1986). It is also defined as the field of dentistry that is concerned with treatment and management of malocclusion (Cobourne and DiBiase, 2015). Malocclusion does not represent a disease but a deviation from the normal occlusion in which may vary from a single slightly deviated tooth position to a group of teeth or even the jaws. What is defined as normal varies and depends on several factors such as ethnic and individual differences and cannot be generalized. In a sense, normal occlusion can be defined as the preservation of health of the oral components and their functions of mastication, speech, and deglutition , within the aesthetic parameters of the individual (Kharbanda, 2009). It is therefore important to understand and define malocclusion, its classifications, and its causes.

2.1 Defining malocclusion

It was Edward Angle who proposed the first detailed classification of malocclusion between the years of 1899 to 1907 using the first maxillary molar as a key of his classification. He believed that they were the largest teeth, firm in their attachment, hold a key location in the dental arch, and they are most frequently teeth found compared to other teeth. By his definition, Class I occlusion is when the mesiobuccal cusp of the first molar in the maxillary occludes the mesiobuccal groove of the mandibular first molar. Class II is when the is when the mandibular first molar is positioned distally to the first maxillary molar. Class III is when the mandibular first molar is positioned mesially to the maxillary first molar (Angle, 1968, Proffit et al., 2007).

Later on, other classifications were introduced such as the British Standards Institute that classifies malocclusion based on the incisors position. It defines Class I occlusion is when the lower incisor tips occluded or lie below the cingulum plateau of the upper incisors. Class II is when the lower incisor tips occlude or lie posterior to the cingulum plateau of the upper incisors. This classification is further subdivided into two divisions based on the maxillary incisors position: Division 1 is when the overjet is increased with upright or proclined upper incisors. Division 2 is when the upper incisors are retroclined, with a normal or increased overjet. Class III is when the lower incisor tips occlude or lie anterior to the cingulum plateau of the upper incisors (Kharbanda, 2009, Cobourne and DiBiase, 2015). Skeletal classifications were also introduced later and has evolved over the years with clinical experience and the introduction of cephalometric radiography.

Cephalometric radiographs were introduced in 1931 which provided a clinical tool for the study of dental malocclusion, the underlying skeletal structure, and the relationship of the jaws. Since that time it has been used by several researchers who laid the foundations of cephalometric analysis to be used by clinical orthodontists and researchers to this very day (Broadbent, 1931). In 1943 Herbert Margolis was the first to analyze the mandibular incisors relationship to the mandibular plane. Shortly after, William Down introduced Down analysis in 1948 which a cephalometric analysis used to diagnose the lateral skeletal pattern and denture profile of a subject. Although his analysis was presented as a method to quantify the relationships of the skeletal components of the face, later it was used as a method of skeletal classification for orthodontic treatment. He considered that the sagittal position of the chin played a great importance in determining facial types. One of his measurements is the facial angle which is the posterior inferior angle formed at the intersection of the Frankfort plane and the facial plane which extends from Nasion to Pogonion. This angle normal range is considered to be within 82^o to 95^o. Also, there is the angle of convexity which measures the degree of the maxillary basal arch at its anterior limit in relation of the facial profile. The angle of convexity normal range is considered to be within $+10^o$ to -8.5^o (Downs, 1949, Downs, 1952, Downs, 1956, Wahl, 2006a).

Steiner has also introduced his Steiner analysis in 1953 which included skeletal, dental, and soft tissues parameters. Among the many measurements used is the ANB angle which assess the relationship between the maxilla and the mandible. This angle is calculated as the difference between SNA and SNB angles. SNA angle is formed between Sella Nasion plane and a line drawn from Nasion to point A which is the deepest point on the curved profile of the maxilla between the anterior nasal spine and alveolar crest. SNB angle is formed between Sella-Nasion Plane and point B which is the deepest point on the curved profile of the mandible between the chin and alveolar crest. He defines the normal relationship of the two jaws within the range of two to four degrees which is corresponded to Angle Class I occlusion. When the ANB value exceeds four degrees it is associated with Class II malocclusion. If the ANB angle value is less than two degrees or if it is a negative value it is associated with Class III malocclusion. Pancherz analysis was developed in 1982 to assess the changes that took place after the conclusion of orthodontic treatment on a skeletal and sagittal dento-alveolar level (Steiner, 1953, Pancherz, 1982).

Holdaway introduced his analysis in 1983 which focused strictly on the soft tissues with one exception of a skeletal variable measured between point A to the hard tissue facial plane. He also introduced and the H-line, also known as the harmony line, which is drawn tangent from the tip of the soft tissue chin to the vermillion of the upper lip. He considered these measurements to be a good way to provides assessment of the skeletal convexity in relationship with the lower lip position and provides a guide to achieve the needed dental relationship to produce a facial harmony. Ideally, the skeletal profile convexity is within the range of +2 to -2 mm (Holdaway, 1983, Holdaway, 1984).

This accumulated effort to understand skeletal malocclusion has provided a classification that derives its bases from Angle's classic classification. Skeletal class I can be defined as an orthognathic face that features a straight facial profile, ANB angle, facial angle, and angle of convexity are within normal range. Class II is a retrognathic face, due to a prognathic maxilla or a retrognathic mandible, which features a convex facial profile, increased ANB angle, reduced facial angle, increased angle of convexity. Additionally, a backward rotation of the mandible may be present and varying in severity. Class III is a prognathic face, due to a retrognathic maxilla or a prognathic mandible which features convex facial profile, decreased ANB angle, increased facial angle, decreased angle of convexity, and a prominent chin (Kharbanda, 2009, Cobourne and DiBiase, 2015).

2.2 Prevalence of malocclusion

Malocclusion is regard as a variation of normal morphology rather than a disease and its often associated mostly with industrial societies although it can be found in developed countries and in fact all over the world with certain malocclusion traits are more common in certain populations. Malocclusion varies in frequency based on many factors but it is clear that orthodontic treatment needs are higher in modern generations than the previous ones. In fact, studies that compare archaeological records with current population has confirmed that malocclusion is becoming more common over the years with increased occlusal variations taken place within generations (Evensen and Øgaard, 2007).

The prevalence of malocclusion varies in different parts of the world and it is subjugated to several considerations such as ethnicity and social status. In general, the prevalence of malocclusion is considered to be between 15-20% for Class II division 1, 10% for Class II division 2, and approximately 3% for Class III (Mitchell and Mitchell, 2014). In the United States Class II malocclusion prevalence was reported to be 34%. India is reported to between 10 to 15%, while Saudi Arabia is 16% (de Muñiz, 1986, al-Emran et al., 1990, Kharbanda, 2009).

In Malaysia, a study was conducted on a 1519 school child between twelve to thirteen years old form twenty different government schools to evaluate the needs of orthodontic treatment. It was indicated that 19% had definite malocclusion problems and 7% of them are required mandatory orthodontic treatment. Although the study did not focus on the proportion of different types of malocclusions it was noticed that the majority of malocclusion were the overjet and open bite (Esa et al., 2001). In the

United Kingdom it is estimated that 35% of twelve year old are indicated for orthodontic treatment while in the United States it is considered to be to be 25% with 16% of them required mandatory treatment (Proffit et al., 1998, Chestnutt et al., 2006).

Ethnicity is one of the factors that plays a role in malocclusion. Class II malocclusion is considered common in Caucasian, Middle Eastern, and Indians populations while Class III is often associated with East Asian societies (Lew et al., 1993a, Soh et al., 2005a, Hardy et al., 2012).

2.3 Aetiology of malocclusion

2.3.1 Role of genetics

It was theorised that discrepancies between the jaws can be genetically inherited. Genes are responsible for controlling growth patterns in soft tissues and regulate bone resorption and deposition which in turn influence growth pattern. However, can growth pattern be inherited? Several studies have been conducted to answer these questions and although the studies were conducted in different geographic locations with different methodology approach and the ages of individuals varied it was found that the craniofacial characteristics are highly inheritable especially skeletal rather than dental and vertical more than sagittal. For example, mandibular prognathism is highly associated with familial inheritance as demonstrated by Watanabe (Johannsdottir et al., 2005, Watanabe et al., 2005, Baydaş et al., 2007).

However, dental anomalies can be inherited as well such as palatally impacted canine, absence of lateral incisors, and microdont. This can be more evident if a familial bond is present (Peck et al., 1994). The closer the family link, the more evident the degree inheritance of craniofacial characteristics such as demonstrated in twin studies which shows similar dental arch dimensions and tooth sizes but had very little in common in occlusion pattern such as the overjet and overbite (Townsend et al., 2009). Although the dental arches and the presence of dentitions and their size are largely influenced by genetic factors it could be argued that malocclusion, especially non-skeletal such as dental crowding, is actually is subjected to environmental factors rather than genetics (Howe et al., 1983).

2.3.2 Role of pathology

There are several pathological conditions that causes direct malocclusion. Undiagnosed bilateral mandibular fractures and the glenoid fossa dislocation can result in an anterior open bite due to the lack of ramus height. The severity of the outcome is directly influenced by the type of injury and age of patient (Cobourne and DiBiase, 2015). Ankylosed condyle from previous fractures can restrict mandibular growth causing ramus deformation, and eventually a facial asymmetry can be observed accompanied by Class II malocclusion. Medline deviation and anterior open bite can also be present if the mandible is restricted from lateral movement (Yamashiro et al., 1998).

Certain pathological diseases can also affect growth in specific sites which in turn result in skeletal malocclusion discrepancies. For example, patients with Crouzon's syndrome and Apert's syndrome are suffer from cranial sutures premature fusion which results in retrognathic maxilla and prognathic mandible due to impaired maxillary growth. Another example is gigantism which is also a pathological hormonal disease that can cause excessive mandibular growth leading to a Class III malocclusion (Nurko and Quinones, 2004, Letra et al., 2007).

2.3.3 Role of environmental factors

Soft tissue balance is what influences developing dentition. Lips, cheeks, and tongue control the position of erupting teeth. Although mastication is a high force, it is short in duration. On the other hand, soft tissues apply low and continues force on the teeth. It is this balance that influences the teeth position and any alteration to the soft tissue balance due to habits such as digit sucking, incompetent lips, and mouth breathing can drastically change the normal tooth position and lead to malocclusion (Cobourne and DiBiase, 2015).

Non-nutritive sucking habits such as digit or pacifier sucking is a habit that exists in some children in the early years of life although digit sucking is more prevalent than pacifiers. However, if this habit persists beyond the age of two years it can have a great influence on teeth position during mixed or early permanent dentition which can lead to anterior open bite, increased overjet, increasing mandibular width, narrowing maxillary arch width and increasing its length, and a tendency for posterior cross bite. The maxillary incisors are pushed buccally because of the continues unbalanced force applied by the thumb on the palatal side of the maxillary incisor's while at the same time pushing the mandibular incisors labially. This also causes the posterior teeth of both jaws to break contact to each other thus increasing cheeks pressure while lowering the tongue position away from the upper arch all of which contributing in increasing the open bite. As a consequence of this malocclusion an adaptive behaviour is created by the tongue which fills the anterior open bite during swallowing. These occlusal changes may in fact continue even after cessation of the habit and the change could be permanent if continued beyond the mixed dentition stage (Katz et al., 2004, Góis et al., 2008).

Mouth breathing is often associated with nasopharyngeal obstruction. However, it is also linked to anterior open bites and it can also be seen in posterior cross bite and Class II malocclusion. Children suffering from mouth breathing are characterised with increased facial vertical dimension and sleeping disorders such as snoring and obstructive sleep apnoea as well as the lips adapting to an open posture during rest. In severe airway obstruction, or total airway obstruction although rare, the head posture is changed by extending the neck resulting in a backward downwards growth rotation of the mandible (Woodside et al., 1991, Varrela, 2006, Katyal et al., 2013).

Unbalanced muscular activity could cause malocclusion. Certain conditions such as muscular dystrophy and cerebral palsy can cause backward downwards growth rotation of the mandible accommodated by an increase in the lower facial height and an anterior open bite which results in reduced bite force which eventually alters the masseter muscles fibers (Hunt et al., 2006).

Diet can also contribute in changing muscular activity. If the diet is composed of hard to chew substance it could increase masticatory muscles function which in turn is transferred to the jaws influencing bone deposition and sutural growth compared with individuals whose diet consists of soft food (Mao et al., 2003, Kiliaridis, 2006). Hard diets require strong mastication that constantly stimulates facial bones growth. In contrast if the diet consists of mostly soft energy-rich food this can lead to underdeveloped jaws and lack of arch space leading to crowding.

It is believed that the mastication muscles influence bone growth and remodelling by their attachment to the periosteum. Animals studies have shown that mastication muscular activity effects bones growth, size, and mass (Varrela, 2006). On the other hand, it is evident that when atrophy is induced to the master muscles it affects bone morphology. Since there was no force excreted by theses muscles it was noticed that the ramus height and mandibular length decreased (Tsai et al., 2009).

Environmental factors influence bone growth and muscular activity resulting in occlusion implications. By manipulating muscular activity, so orthodontists can apply change to the jaws in a way that benefits the patient into achieving a balanced harmony face through functional appliances. These appliances rely on the forces generated by the stretch of the oral and facial muscles activity to influence the position and function of the mandible which generates forces that induce orthodontic and orthopaedic change (Bishara and Ziaja, 1989).

2.4 Functional appliances

Functional appliances are orthodontic appliances that utilize the forces generated by the muscles to accomplish skeletal and dental changes through growth modification. Functional appliances can be removable or fixed based on the mode of action and design (Bishara and Ziaja, 1989). The removable orthodontic appliances use and development thrived in Europe generally while it was almost neglected completely in the United States. Probably because American orthodontists were greatly influenced by Angle's approach of individual tooth movement which had little impact on the European Orthodontic Society. Another reason is the lack of precious metals in Europe at the time which was used for fixed appliances because of their social systems which forced orthodontists to pursue alternative methods of malocclusion corrections using removable appliances made of available material. The earliest documented use of a functional appliance belongs to Norman W. Kingsley in 1879. The appliance consisted of a removable plate with molar clasps, labial wire and a bite plane extending posteriorly. The device was used to position the mandibular forward. The purpose of this device as he described it "The object was not to protrude the lower teeth, but to change or jump the bite in the case of an excessively retreating lower jaw" (Wahl, 2006b).

Other appliances were introduced later which addressed individual teeth rather than growth guidance such as Crozat appliance (Lamons, 1964). The Monobloc which was developed by Pierre Robin in 1902 is considered to be the first true removable functional appliances. Initially it was designed to treat children who suffered glossoptosis syndrome, also known as Pierre Robin syndrome, by using the functional activity of the facial muscles to treat malocclusion by correcting the relationship of the jaws. However, in 1920 Viggo Andersen developed the activator appliance, also known as Norwegian system, which was the first functional appliance to be widely used and accepted (Wahl, 2006b).

A wide range of functional appliances exist today and they can be categorized into three major types, passive tooth-borne appliances, active tooth-borne appliances, and tissue-borne appliance. Passive tooth-borne appliances rely on the facial muscles activity and soft tissues stretch to achieve desired treatment effects. Examples of this type are the Bionator, Herbst, and Twin block. Active tooth-borne appliances are designed to induce tooth. This group include expansion activator, orthopaedic corrector, and many variations and modifications from the passive tooth-borne appliances that are designed to induce tooth movement by adding springs or expansion screws. Finally, the tissue-borne appliance basically relies on soft tissues to induce mandibular posture changes and alter the facial soft tissue contour. The Frankel appliance, also known as the function regulator, is an example (Bishara and Ziaja, 1989). Most functional appliances are removable but some of them are fixed such as the Herbst appliance. Usually functional appliances are designed to be worn full time but that depends on the purpose of treatment and its current stage weather it in the active stage, support, or retention. It is important to note that if the removable appliance is not worn more than four or six hours a day it would fail to produce any orthodontic or orthopaedic effect. This is attributed to the cellular response to functional appliances (Proffit et al., 2007).

2.5 Mechanism of action

Patients with malocclusion are often referred to orthodontists mainly for aesthetic improvement. In Class II malocclusion the increased overjet and the undesirable convex facial profile may lead to negative self-image and low self-esteem. Treatment in such cases focuses on solving the dento-skeletal discrepancy in order to obtain a favourable facial aesthetics (Ward, 1994, Tung and Kiyak, 1998, O'Brien et al., 2003b, Marques et al., 2006). Each functional appliance is dedicated for specific treatments of malocclusion. For Class II malocclusion treatment these appliances rely on the forces generated by the stretch of the oral and facial muscles activity to influence the position and function of the mandible. This is thought to generate forces that are carried out to the teeth, periodontal structures, temporomandibular joints and basil bone to induce orthodontic and orthopaedic change (Bishara and Ziaja, 1989).

Dento-alveolar changes include retroclination of maxillary incisors, inhabitation of maxillary molars and mandibular molars mesial migration. Skeletal changes include maxillary restriction and increment in mandibular growth and influencing the condylar and glenoid fossa position (Mills and McCulloch, 1998, Chintakanon et al., 2000, Jena et al., 2006, Alves and Oliveira, 2008).

2.6 Timing of treatment

The optimal time to use functional appliances for malocclusion treatment is within the active growth period. Treatment consists of two phases the first is therapy using functional appliance to correct jaws discrepancies and the second is correcting dental malocclusion using fixed appliance (Kuijpers and Kuijpers-Jagtman, 2008). The two-phase treatment starts early and usually the functional appliance is issued during the mixed dentition period. Another method is issuing the appliance during the puberty peak which is identified assessing cervical vertebral maturation (CVM). The CVM is classified into six stages and it was found that stage three marks the pubertal peak which is the appropriate time to issue the appliance (Baccetti et al., 2000). It was found that greater skeletal effects can be achieved during this peak period than those treated before peak period (Malmgren et al., 1987). A recent case report pointed a similar finding (Neela, 2018).

One phase therapy is consisting of using the fixed appliance only which usually starts when all permanent teeth had been accounted for and corrections of dental malocclusion is carried out simultaneously or in sequence with jaw discrepancies corrections. It is argued that the results would be the same either undergoing two phase early treatment or undergoing a one phase treatment and a two phase treatment would only prolong treatment (Tulloch et al., 2004a). It is worthy to mention that it was stated in a case report that skeletal and dental changes can be induced even if a functional appliance is chosen for treatment even after the pubertal peak (Aminian et al., 2017). However, the effects are limited, and such course of treatment should be planned with caution while keeping the objectives of desired treatment effects in mind. The age and growth pattern are the key to decide which course of treatment would be suitable. In young patients facial growth especially the forward growth of the mandible occurs during pubertal growth spurt which should be seen as an advantage to manage Class II malocclusion (Baccetti et al., 2000, Kuijpers and Kuijpers-Jagtman, 2008).

Treatment timing is one of the major concerns for Twin block treatment. In young patients, growth modification using functional appliances followed by fixed appliances therapy has been advocated as an appropriate treatment approach (Tulloch et al., 2004b). The Twin block full effectiveness is achieved in young patients when growth spurts especially in the mandibular is at its peak (Baccetti et al., 2000, Al-Anezi, 2011).

2.7 The Twin block

The Twin block appliance is a functional appliance that was developed by William J. Clark (Clark, 1982). Since its creation it has gained a wide popularity among orthodontic practitioners and it was voted as the preferred choice for treating Class II malocclusion by the British Orthodontist Society (Chadwick et al., 1998). The Twin block is used mainly to correct skeletal Class II and Class III malocclusion both of which are considered prevalent types of malocclusion in several parts of the world (Lew et al., 1993b, Soh et al., 2005b, Gelgör et al., 2007, Fida, 2008).

The Twin block comprises of removable upper and lower acrylic plates which include posterior bite planes with inclined edges aligning to each other in a 70^o angle. The acrylic planes cover the upper first molars and second premolars while the lower blocks cover the second premolars region. When the acrylic planes interlock in occlusion act as a guiding mechanism by holding the mandible in a downward forward posture yet allowing the mandible movement. When the bite planes are engaged during occlusion they prevents the mandible from returning to its distal position and allowing it to adapt to its new protrusive position (Clark, 1988).

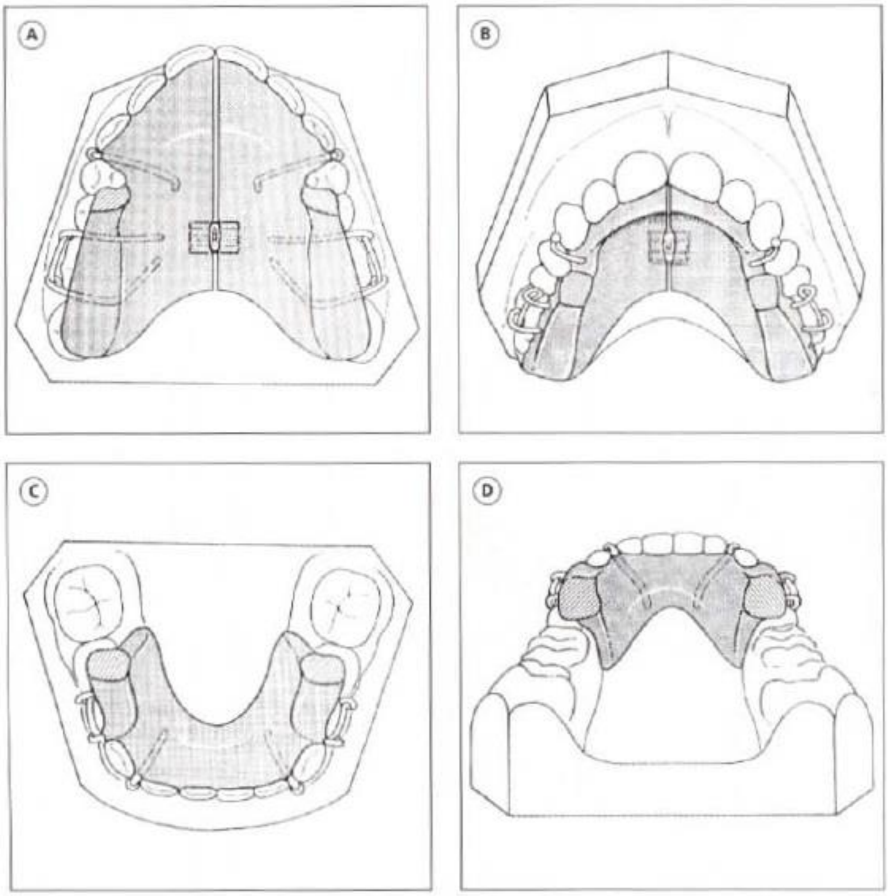

Figure 2.1 The Twin block, (A) upper appliance occlusal view, (B) upper appliance frontal view, (C) lower appliance occlusal view, (D) lower appliance rear view (Clark, 2002).

The upper appliance includes a very important component which is the maxillary expansion screw. The upper appliance is retained by a two arrow head clasps that resides on the first molar. The long labial bow that extends distally to the first premolars also helps in retaining the appliance. The lower appliance is held by ball ended clasps that resides on the incisors and the delta clasps that resides on the first premolars. The delta clasps may also reside on the deciduous first molar in mixed dentition stage (Clark, 2002). Several modifications can be added to the upper appliance such as adding a coiled tube to house to use face bow simultaneously with the Twin block appliance (Samuels et al., 2000). Another modification is the replacement of the lower ball ended clasp on the lower appliance with an acrylic pad (Van der Plas et al., 2017). The amount of mandibular movement is subjected to height of the posterior bite planes which is determined during bite registration by the orthodontist and midline functional discrepancies are correct during this stage (Shah and Sandler, 2009, Clark, 2010).

2.8 Bite registration

Optimally for Class II division 1 it is suggested that the interincisal space should be registered as 4 mm in order to provide a vertical opening of 1 to 2 mm in the molar region which is equivalent to 4 to 5 mm acrylic thickness in the premolar region. This is done to open the bite beyond the freeway space in order to prevent the mandible from returning back to its original position while at the same time allowing the patient to eat and speak normally. In severe deep bites the interocclusal clearance may be increased and the bite is registered as a 2 mm in an edge to edge interincisal relationship (Clark, 2002). Other authors have suggested that the wax bite thickness in the premolar region should be between 7 or 8 mm (Dyer et al., 2001, Shah and Sandler, 2009). Certain disadvantages can be notice with such technique. The patient would be discomfort with the appliance because of the oversized blocks which can be seen in the excessive lower facial height, difficulty in chewing food, lost lip closure, pain attributed to muscle strain, speech impediment, and social appearance. Additionally, the temporomandibular joint may be affected as well because of the development of a posterior open bite during treatment and lower molars may be prevented from erupting if the appliance is used during the mixed dentition phase. All leading to poor compliance of the patient hence the treatment outcome (Clark, 2010).

The mandibular forward position is also controlled by the orthodontist when registering the bite. The incisors are brought to an edge-to-edge relationship as much as possible in order for the patient to feel comfortable with new protruded jaw position. In large overjets that exceeds 10 mm, the edge-to-edge should not exceed the 70% of the total mandibular protrusive path to remain in the range of the mandibular physiological movement limits (Clark, 2010). Another method is the gradual advancement of the bite to its maximum potion which is seen in other functional appliances (Falck and Fränkel, 1989). This is done in small stages in order to ensure that it does not affect the patient speech, increase cooperation, and reduce tension of the facial muscles. However, there does not seem to be any difference in results between the two techniques (Banks et al., 2004).

The Twin block appliance is designed for a full-time wear to induce faster adaptation to neuromuscular changes to induce skeletal and dental changes. It is robust, simple in design, cost-effective, easy to repair, does not require special laboratory procedures or expensive equipment to fabricate, suitable for permanent and mixed dentition, allows mandible movement which means it is less obstructive to oral functions and speech, can be used with fixed appliances or extra-oral appliances, and rapidly reduce the overjet allowing quick correction of the malocclusion and reducing the risk of trauma to protrusive incisors (Clark, 2002, O'Brien et al., 2003b, Årtun et al., 2005, de Paula et al., 2009, Bhaskar, 2015).

One of the major concerns of the Twin block that it relies largely on the patient's cooperation creating a potential problem. There are many factors that influence the patient compliance one of which is the social and economic status of the patient. Other factor that has huge impact on treatment results is the self-motivation which result in good treatment outcome unlike patients who did not seek the treatment themselves in the first place but instead were indicated for treatment by a clinician or rather forced by any other external factors such as parents for treatment. You would expect little cooperation and indulgence over the treatment course, skipping appointments, limiting the wear of appliance in night time only or not wearing the appliance at all, not wearing the appliance during clinic follow ups, the appliance does not showing any signs of usage or wear, and ignoring to inform the orthodontist of appliance problems such as difficulty in adapting for any reason or breakage (Albino, 2000, Daniels et al., 2009, Al-Anezi, 2011).

Usually most patients adapt to the appliance usage quickly within a week but when treating Class II in a non-compliant patient or when the patient cooperation is doubtful the orthodontist may refer to fixed functional appliance to resolve this issue (Sood, 2010). It is worthy to note that the Twin block size is relatively small compared with other functional appliances and has no visible anterior acrylic portions except when replacing the ball ended clasps on the lower appliance with an acrylic pad. This minimizes any speech interference which makes the appliance more acceptable by the patient (Toth and McNamara Jr, 1999).

Twin block may not be suitable for lower proclined incisors (Al-Anezi, 2011). This problem is generally observed in functional appliances and it is referred to the mandible attempts to revert to the normal resting position causing the lower incisors to exert a protrusive movement induced by the lingual appliance components (Proffit, 2007). This unwanted inclination may increase the tendency for relapse later. Adding Southend clasps in the anterior region of the lower appliance can limit the incisor proclination (Trenouth and Desmond, 2012). Acrylic capping is recommended to prevent labial tipping of the lower incisors in functional appliance treatment (Mörndal, 1984). This modification to the Twin block design showed it can minimize lower incisors proclination (Sidlauskas, 2005). A recent study compared between two types of Twin block design, one with acrylic capping the other with ball end clasps, and if they had any effect on lower incisors proclination. They stated that the lower incisors proclination could not be limited regardless of Twin block design or treatment duration (Van der Plas et al., 2017). The controversy between the two studies can be attributed to the methodological approach each researcher chose to tackle the problem. The proclined lower incisors can be corrected during the second stage of orthodontic treatment by using interdental stripping when the fixed appliance is placed (Tulloch et al., 1998).

Furthermore, undesirable treatment effects may occur such as undesired increase in the vertical facial dimension, clockwise rotation of the maxillary plane, and limited increase in mandibular growth (Illing et al., 1998, Lund and Sandler, 1998, Mills and McCulloch, 1998, Mills and McCulloch, 2000).

2.9 Treatment stages

Twin block is divided into three stages of treatment, the active phase, support phase, and retention phase.

2.9.1 Stage 1: Active phase

The active phase is when the Twin block is used in Class II to correct the retruded mandible into a Class I relationship with the maxilla. This is accomplished when the appliance interlocks during occlusion and the inclined planes over the premolars areas guide the mandible into a downward forward posture. Before fitting the appliance, it is checked for clearance in the premolar regions, comfort when the patient is wearing it, sharpness, pimples, and if there is any need to modify the clasp so they may not damage the margins of the gingiva. However, when first wearing the appliance excessive salivation, pain, and discomfort maybe expected. The patient should be encouraged and motivated to continue wearing the device and try to adapt to it in speech, night time wearing, and eating (Clark, 1988).

The activation of the appliance is done within the first week usually in the first two or three days. The expansion screw is turned one quarter per week. After four weeks in the second visit the appliance is checked for retention. The third follow up is within six to eight weeks the patient should feel uncomfortable when the tying to bring the mandible into its original position when the appliance is removed. This indicates the adaptation of the neuromuscular adaptation of the mandible to its new protruded position which is also marked by the reduction of the overjet and sagittal correction. Follow up visits are continued every six or eight weeks. The sagittal correction is achieved usually within four to six months. By the end of this stage the distal occlusion, overjet, and overbite are corrected. Sagittal correction is achieved before the vertical development of posterior teeth is completed. The vertical dimension is controlled depends on the adjustments of the occlusal blocks. This phase last averagely between six and nine months to achieve treatment goals of skeletal correction when the mandible is its new protruded position which is also marked by the reduction of the overjet and sagittal correction (Clark, 2002, Kharbanda, 2009).

When dealing with deep overbite the acrylic blocks can be reduced selectively in stages to allow for posterior teeth to erupt and increase vertical dimension. The removal should be confined within the distal areas and it is crucial to exclude the anterior edges of the blocks until an appropriate occlusion is formed when the molars erupt. A minimal molar clearance should be obtained within 1 to 2 mm to prevent the tongue from spreading laterally between the teeth and create unwanted problems. With each visit the upper block is reduced to encourage the lower molars eruption until the acryl is removed completely from the upper blocks allowing the lower molars to fully erupt into occlusion. In treatment of vertical growth patterns and anterior open bite the blocks remain without reduction during the course of treatment (Clark, 2010).

2.9.2 Stage 2: Support phase

This phase is used to preserve the incisors relationship while the posterior buccal segments takes proper occlusion position. During this phase, a fixed appliance may be used to level the lower arch if necessary. This step is important when faced when a large posterior open bite is present after the active treatment. It is also important when faced with large overjet of 15 mm and when a combination of maxillary protrusion and mandibular retrusion is present. In the support phase, the lower appliance is not used at this stage and the upper appliance is modified by adding an anterior inclined plane which includes a labial bow that engages with the lower incisors and canine. Other modifications to the appliance may include steeper blocks or adding posterior inclined blocks to counter lateral spread of the tongue in posterior open bites. The desired bone remolding occurs when the occlusion settles and this is achieved by using the appliance full time. This phase may take between three to six months (Clark, 1988, Clark, 2002, Trenouth, 2002, Clark, 2010, Singh et al., 2016). However this step seems rather optional if not faces with any large discrepancies in the posterior buccal segments and it can be skipped directly into the retention phase (Nayak et al., 2011).

2.9.3 Stage 3: Retention phase

Relapse can be defined as the tendency of teeth to return to their original position after orthodontic treatment. This includes skeletal corrections reverting to the pre-treatment position (Melrose and Millett, 1998, Destang and Kerr, 2003). Management of relapse is focused mainly on preventing it by holding the teeth in their anatomical and functional positions after the conclusion of orthodontic treatment through what is known as the retention phase. Other management include overcorrecting malocclusion as an unavoidable relapse occurs such as in deep overbites (Nanda and Nanda, 1992). Eliminating the cause of malocclusion, if it is caused by a habit such as thumb sucking, can reduce relapse occurrence (Destang and Kerr, 2003). Additionally, corrections carried out during growth, such as a newly acquired skeletal mandible position, are unlikely to relapse (Reitan, 1959, Nanda and Nanda, 1992).

Retention is an indivisible part of orthodontic treatment and should be planned before executing treatment. Relapse can be attributed to three major reasons. First, the periodontal tissues must settle down and recognize the changes that occur after active orthodontic treatment (Krishnan and Davidovitch, 2006). Second, treatment result can be altered because of changes produced by growth. Differential growth rates may also alter the jaws relationship and therefore contribute in repositioning the teeth. Finally, teeth may tend to relapse after treatment under the constant soft tissues pressure if their position is inherently unstable (Proffit, 2007). Other factors can influence relapse such as age, gender, ethnicity, and systemic disease (Kharbanda, 2009).

This retention phase varies in duration and retainer type and requires careful management. It is difficult to identify the appropriate retention duration for each individual patient because of the variety of malocclusions treatment procedures and individual differences of growth rate (Melrose and Millett, 1998). Since functional appliances modify growth the retention stage should continue until growth is completed (Bock and Ruf, 2008, Lerstol et al., 2010). Studies indicate that a very slow growth continues throughout adult life and the same pattern of growth that led to the malocclusion can contribute in relapse of treatment many years after its completion (Lewis and Roche, 1988, Nanda and Nanda, 1992). Obviously, this method is unpractical because growth is a continuous process and no patient would be willing to continue using the appliance for years.

When it comes to the retention phase after Twin block therapy the duration is between three to nine months and appliance usage is reduced to night time only when the occlusion is fully established (Clark, 2010). This phase is also known as the transition period in which a fixed appliance is used later to level the lower arch and complete the treatment (Fleming et al., 2007).

Clinical scenario dictates the orthodontist course of action. Once therapy is completed the orthodontist may continue with the fixed appliance immediately without an interim retention phase. This step is possible if the patient is cooperative, has good oral hygiene, and completed the permanent dentition eruption (Fleming et al., 2007). Other authors advised that a three months retention period is necessary for any relapse to be identified and anchorage requirements for fixed appliance can be evaluated (Gill and Lee, 2005, Sharma and Lee, 2005). If the active treatment is completed before the permanent teeth has erupted the Twin block is used as retainer and fixed appliance use is delayed until permanent teeth are in place in order to preserve the any achieved alignment of the lower incisors and prevent any mesial permanent molar drifting while the deciduous molars exfoliate (Fleming et al., 2007, Brierley et al., 2017, Clark, 2010). The orthodontist should check on the patient in regular visits until permanent teeth are fully erupted which should start the second phase of comprehensive treatment to correct the remaining malocclusion.

2.10 Skeletal, dental, and dento-alveolar changes after Twin block therapy