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Changes in Dental Arch Dimension among Dental Class II Patients after Rapid Maxillary Expansion Therapy

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…………….. to my beloved parents, for their love and encouragement.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Background

A task that many orthodontists undertake routinely is to create the additional spaces in dental arches of dental crowding patients with tooth size-arch size discrepancies. For patients with severe dental crowding, the choice of tooth extraction to gain space is clearly recognized. An orthodontist who decides to alleviate crowding without extractions might consider the alternative methods aimed to relieve tooth size-arch size discrepancies which include interproximal reduction of teeth or “stripping”, molar distalization, dental expansion, and orthopedic expansion of the maxilla or combination of all these alternatives.

Orthopedic maxillary expansion treatments have been used for more than 140 years and have been popularized since the mid-1960s. The first reference of the expansion procedure was introduced by Angell[1] and White[4] in 1860. Angell set a jackscrew on the upper dental arch across the roof of the mouth of a fourteen-year-old girl. White placed a spiral spring through upper dental arch to force the teeth into the dental arch. This treatment is used for constricted maxillary arch and tooth size-arch size discrepancy patients. It is stated that this method is an effective and stable correction of transverse deficiencies [3,5,22].

Although the objective of orthopedic maxillary expansion treatment is to widen the constricted maxilla in narrowed palate vault patients, it has been shown by many authors the additional benefits of this procedure [3,5,7,8,11,12]. It can provide additional spaces in dental arches to increase dental arch dimensions to resolve borderline crowding in some mixed dentition patients. In addition, this procedure can be used to facilitate maxillary canine eruption, provide the spontaneous correction of mild to moderate Class II and Class III malocclusion, improve nasal airflow in patients with nasal stenosis, and “broaden the smile”. Moreover, Haas noticed in 1961[5] that the expansion of lower dental arch will be occurred after the maxillary expansion which is followed by the increase in mandibular arch width. McNamara[3] speculated that the position of the mandibular dentition might be influenced more by maxillary skeletal morphology than by the size and shape of the mandible.

There are three treatment alternatives of the maxilla expansion in orthodontics which are evaluated on the basis of the frequency of the activations, magnitude of the applied force, duration of the treatment, and the patient’s age. These are rapid maxillary expansion (RME), slow maxillary expansion (SME), and surgical-assisted RME (SARME). Both RME and SME are indicated for growing patients, whereas SARME is the alternative selected for non-growing adolescent and young adult patients[2].

The aim of orthodontic treatment for the mixed dentition patients with constricted maxilla and discrepancies between tooth size and arch dimension is to correct the skeletal discrepancy and to gain additional space in the dental arches to resolve crowding. Rapid maxillary expansion (RME) therapy can be used effectively for this treatment approach. This procedure increases the upper arch transverse dimensions mainly by separation of the two maxillary halves (orthopedic effect), followed by buccal movement of the posterior teeth and alveolar processes (orthodontic effect). It shows both significant skeletal and dental effects.

1.2 Objectives of the study

This study was designed for specific purposes:

1.2.1 To assess and evaluate the dental treatment effects after rapid maxillary expansion followed by fixed appliance treatment on the maxillary and mandibular dental arch dimensions among mixed dentition patients at pre-treatment (T1), after expansion and during orthodontic treatment (T2), post-treatment (T3), and post-retention (T4) assessment stages.

1.2.2 To examine the changes in the maxillary and mandibular dental arch dimensions in the transverse, sagittal, and vertical dimensions, of the patients and control group in all observation periods (T1,T2,T3,T4).

1.2.3 To compare the difference changes in maxilla and mandibular dental arch dimensions of the mixed dentition patients at pre-treatment (T1), after expansion and during orthodontic treatment (T2), post-treatment (T3), and post-retention (T4) assessment stages to untreated mixed dentition children at four observation periods (T1,T2,T3,T4).

1.3 Statement of the problem

Rapid maxillary expansion (RME) therapy is an effective treatment approach to solve maxillary skeletal constriction and tooth- size arch-size discrepancies in orthodontic practices. The question is whether RME followed by routinely orthodontic fixed appliance treatment could:

1.3.1 Effect on maxillary and mandibular dental arch dimensions by changing intercanine, interpremolar and intermolar widths, arch length, arch depth and arch perimeter in mixed dentition patients at pre-, during, post-treatment, and post-retention period.

1.3.2 Produce stable favorable increases in maxilla and mandibular dental arch dimensions after maxillary expansion followed by fixed appliance treatment in a long-term period.

1.3.3 Increase the maxillary and mandibular dental arch dimensions in orthodontics treated patients when compared with untreated children in the observation periods.

1.4 Significance of problem

There are skeletal and dental treatment effects after the expansion of rapid maxillary expansion (RME) therapy. After expansion, maxilla will be expanded followed by the increase in dental arch dimensions. This increase is needed to gain the sufficient spaces to resolve mild to moderate dental crowding problem in dental arches. Furthermore, there is also the effect on lower dental arch followed by the maxillary dental arch expansion. The measurement of the upper and lower dental arch dimensions from this study showed the dental treatment effects of the maxillary expansion therapy on the upper and lower dental arches from pre-treatment until the post-retention periods.

1.5 Hypothesis (Null)

1.5.1 No difference in the maxillary and mandibular dental arch dimensions measurements at 4 assessment stages: pre-treatment (T1), after expansion and during orthodontic treatment (T2), post-treatment (T3), and post-retention (T4).

1.5.2 No difference in the maxillary and mandibular dental arch dimension measurements between treated sample group at pre-treatment and untreated sample group at the beginning of the observation period.

1.5.3 No difference in changes (T2-T1 changes, T3-T1 changes, T4-T3 changes and T4-T1 changes) between the observation periods of both the treated and untreated sample groups.

1.5.4 No difference in the maxillary and mandibular dental arch dimensions measurements between treated samples group at post-retention and untreated sample group at the end of the observation period.

1.6 Scope and Delimitation

The study research is limited to:

1.6.1 Patients with maxillary constriction and no craniofacial anomalies or syndromes

1.6.2 Patients who have no history of previous orthodontic and orthopedic treatments before the beginning of the assessment period

1.6.3 The group of patients and the control group of children have Angle Class II malocclusion and mixed dentition at the beginning of the observation period

1.6.4 Patients who were treated by non-extraction therapy during the assessment stages at the Orthodontic Department (Poliklinik für Kieferorthopädie) of the Ludwig Maximilian, University of Munich

1.6.5 All of the measurements are done by only one investigator

1.7 Definition of Terms

Angle Class II Malocclusion

The nomenclature of the Angle classification of Class II malocclusion emphasizes on the distal molar relationship of the maxilla and mandible in which the mesial groove of the mandibular first permanent molars articulates posteriorly to the mesiobuccal cusp of the maxillary first permanent molars.

Dental arch dimensions

The magnitude of dental arch in a particular direction. The usual measurement of dental arch dimensions is dental arch width, length, depth, and circumference.

Dental arch depth

The perpendicular distance on maxilla and mandible dental arches from the contact point between central incisors to a lined constructed between the mesial contact points of the first molars and the distal contact points of second deciduous molars/ second permanent premolars[37].

Dental arch width

The transverse diameter from one side to the symmetrical opposite side or from left to right side of the dental arch.

Intercanine width

The distance between cusp tips of the right to the left permanent/ deciduous canines in transverse dimension.

Interpremolar width

The distance between buccal cusp tips of the right to the left permanent first/second premolars or deciduous first/second molars in transverse direction.

Intermolar width

The distance between mesiobuccal cusp tips of the right to the left permanent first molars in transverse direction.

Dental arch length

A sum of distance of the right and left distances from mesial contact points of the first permanent molars to the contact point of the central incisors or to the midpoint between the central incisors if spaced[37].

Arch perimeter / Arch circumference

The circumferential distance which is measured from the distal surface of the second deciduous molar or mesial surface of the first permanent molar around the arch over the contacts points and incisal edges to the distal surface of the second deciduous molar or mesial surface of first permanent molar of the opposite side.

Overjet

The distance parallel to the occlusal plane from the incisal edges of the most labial maxillary to the most labial mandibular central incisor which is defined as the horizontal overlap of the upper and lower incisors.

Overbite

The vertical distance from the incisal edges of upper incisor to lower incisor which is defined as mean vertical overlap of upper to lower central incisors.

2. LITERATURE REVIEW

2.1 HISTORY OF MAXILLARY EXPANSION THERAPY

At present, in routine orthodontic practices, two of the most common observed problems are dental crowding and protrusion of the teeth, both of which derived from discrepancies between the sizes of the teeth and the sizes of the bony bases. Otherwise, unilateral or bilateral crossbite can be also exhibited in the dental arches caused by maxillary skeletal discrepancy; when this skeletal discrepancy is camouflaged by the dentition, crowding is also observed [3].

Maxillary expansion therapy is often indicated in the patients with transverse malocclusions due to skeletal maxillary deficiency. In addition, this therapy is one of the alternative methods of extraction, interproximal reduction or "stripping", and distalization, aimed to relieve discrepancies dental crowding problems, especially in borderline dental crowding which cannot be clearly defined for extraction or non-extraction therapy. Haas[10] stated in 1980 that the palatal expansion therapy is the alternative for the patients with an excellent skeletal pattern who need for a few millimeters of arch length to relieve crowding, even if the extraction of second premolars leads to a concave and exceedingly flat profile. There is frequently difficulty in closing the spaces and even greater difficulty in keeping them closed.

Maxillary expansion treatments have been used for more than 140 years and have been used widely since the mid-1960s. The earliest references to palatal expansion procedures were made in 1860 by E.C.Angell [1] and J.D.White[4]. They showed the maxillary expansion appliances and described their case-study patients in the same journal-Dental Cosmos, 1860. E.C.Angell fashioned a jackscrew across the roof of the mouth of a fourteen-year-old girl to provide space for maxillary canines. The patient was directed to turn the nut of the jackscrew twice daily (Fig 1).

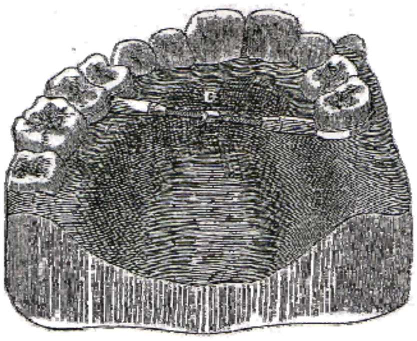


Fig 1: The apparatus to widen the jaw and expand the maxilla arch.

J.D. White placed a spiral spring in a young girl thirteen years of age, as only to act on the first bicuspid to force these teeth into the arch. The patient was informed to come back in two weeks. This plate was fastened to the first molars or bicuspids, and a spiral spring is attached on either side, with the bow of spring extending around behind the front teeth (Fig 2).

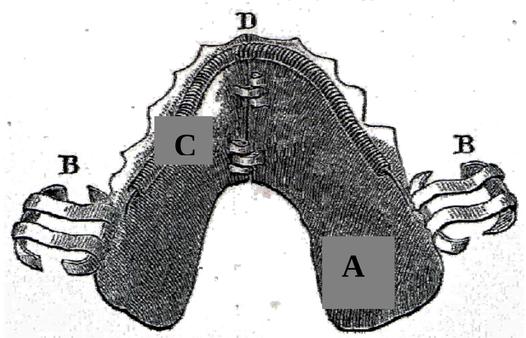


Fig 2: The apparatus shows: A, the plate; B, the crib bands for the first molar; C, the spiral spring; D, the hinge joint.

After the first report of this procedure, it has gone through periods of popularity and decline. In European countries, orthodontists continued the use of the operation and had reported on it through the years: Babcock (1911), Schroeder-Bensler (1913), Landsberger (1914), Huet (1926), Mesnard (1929), Mela (1933), Derichsweiler (1953), Korkhaus (1953), Krebs (1958), Thorne (1960), and others. Schroeder-Benseler in 1913, defined the guidelines of maxillary expansion apparatus for expanding nasal cavity through the midpalatal suture. His apparatus was similar to those of E.C.Angell. He joined the jackscrew to the metal-based crowns on the left and the right posterior teeth (Fig 3) [11].

Fig 3: The apparatus according to Schroeder-Benseler in the year 1913 to widen the nasal cavity.

Derichsweiler[11] (1953) used this appliance (Fig 4) in patients who have maxillary compression or posterior dental crossbite for widening the maxillary skeleton and expanding the dentition. Those patients were directed to turn the screw 3 times daily for 14 days. He retained the plate in upper dental arch after opening of the palatal suture for 3 months in order to stabilize maxillary basal bone during the bone regeneration.

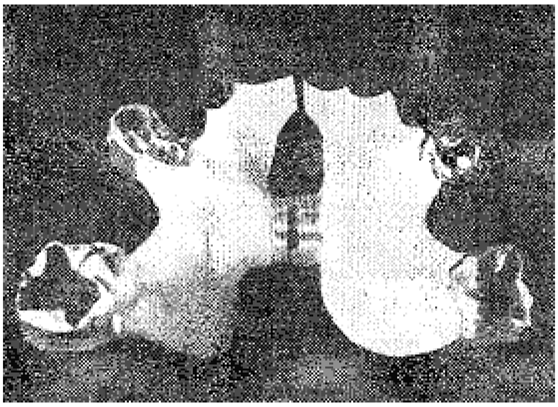


Fig 4 : The apparatus consists of plate and four metal bands on the teeth.

In 1956, Korkhaus reintroduced the procedures in the Unites States of America while visiting the Department of Orthodontics at the University of Illinois. His remarkable cephalometric records of cases treated by palate expansion aroused the curiosity of Allan G. Brodie and the other colleagues, including A.J. Haas[9].

Haas[6] popularized the fixed palatal expander in 1959. He conducted a rapid expansion technique on pigs and reported that: (1) The procedure was apparently pain free; (2) The midpalatal suture offered very little resistance to spreading; (3) Internasal width was increased; (4) Mandibular dental arch expanded in response to altered functional forces resulting from maxillary expansion. He later reported the results of a clinical study of midpalatal expansion in ten patients ranging from nine to eighteen years of age. In this investigation (10 cases were showed), two cases showed a slight decrease in maxillary dental arch width while two showed a slight increase in maxillary dental arch width following retention. The remaining six cases showed no demonstrable difference in the width of the maxillary dental arch at retention and in recent postretention records[7].

It appeared that rapid maxillary expansion (RME) not only corrected maxillary skeletal constriction but also created additional space in the dental arches to relieve dental crowding [2,8]. It showed both significant skeletal and dental results. Haas [5] noticed as early as in 1961 that "When the maxillae are expanded, spontaneous expansion will occur in the lower dental arch, due to altered muscle balance between the tongue and buccinators muscles as they affect the lower dental arch. That is, a permanent increase in maxillary apical base which leads to a spontaneous, permanent and significant increase in mandibular arch width". McNamara [3] assisted the same findings that the position of the lower dentition in patients who underwent rapid maxillary expansion therapy may be influenced more by maxillary skeletal morphology than by the size and shape of the mandible. Following RME, not only is there expansion of the maxillary dental arch, but the lower dental arch as well. The lower arch widening is due primarily to "decompensation," an uprighting of the lower posterior teeth, which often have erupted into occlusion in a more lingual orientation because of the associated constricted maxilla.

2.2 RAPID MAXILLARY EXPANDER (RME)

Maxillary transverse deficiency, in fact, may be one of the most pervasive skeletal problems in the craniofacial region. Signs of maxillary deficiency include one of these three phenomena, ie. unilateral or bilateral crossbites, dental crowding due to tooth size-arch size discrepancies or laterally flared maxillary posterior teeth. These signs of maxillary deficiency often appear together, as might be termed *maxillary deficiency syndrome*. When crowding in the presence of crossbite is observed, the orthopedic treatment of maxillary expansion to correct this skeletal problem is clearly indicated. Otherwise, such patients without crossbites, who have laterally flared maxillary posterior teeth with tipped lingual cusps of the posterior teeth below the occlusal plane, are also candidates for maxillary expansion[3].

Tooth size-arch length discrepancies, according to dental crowding, is one of the most routinely problem in orthodontic practices. This discrepancy can be divided into 3 categories: severe crowding or clear-cut extraction (crowding >

6 mm), mild crowding or clear-cut non-extraction (crowding < 3 mm), and borderline crowding problems (crowding between 3-6 mm) [12]. In patients with mild or severe crowding, the choice of whether to reduce interproximal surfaces of teeth or to extract teeth to gain space typically is obvious. However, the borderline dental crowding patients, the alternative treatment of tooth extraction or stripping is a difficult decision. Maxillary expansion therapy is the another alternative method to gain space in the dental arch. It not only enlarges the constricted maxillae, but also creates additional spaces in the dental arches, therefore, it can be used to resolve borderline dental crowding problem in some patients. Adkin D. et al[15] stated that the maxillary expansion procedure has been the subject of renewed interest in orthodontic treatment mechanics because of its potential for increasing arch perimeter to alleviate crowding in the maxillary arch without adversely affecting facial profile.

There are many alternatives to maxillary expansion therapy which are available for the treatment of the skeletal constricted maxillary arch. When evaluated on the basis of the frequency of the activations, magnitude of the applied force, duration of the treatment, and the patient's age, different mechanics produce three alternatives : rapid maxillary expansion (RME), slow maxillary expansion (SME), and surgical-assisted RME (SARME) [2,3,8,14]. Both rapid maxillary expansion (RME) and slow maxillary expansion (SME) are indicated in growing patients. This is explained by progressive midpalatal sutural closure that increases the resistance of the maxilla to expansion during the late teen years. When RME or SME does not appear to be feasible, SARME is the selected alternative treatment of choice for nongrowing adolescents and young adult patients. This procedure allows for the surgical splitting of the midpalatal suture and widening of the maxilla[2,13].

2.2.1 Types of Rapid Maxillary Expander (RME)

In rapid maxillary expansion (RME) procedures, two types of RME appliances are most widely recognized by many orthodontists. The appliances consist of jackscrew in banded or bonded appliances with the presence or absence of an acrylic pad close to the palate. One type of this appliances is the tooth tissue-borne expander or Haas-type expander[6,17] (Fig 5,6). Following the basic standards of Haas in 1959, it possesses an acrylic pad, which is assumed to distribute the expanding force between the posterior teeth and the palatal vault[16].

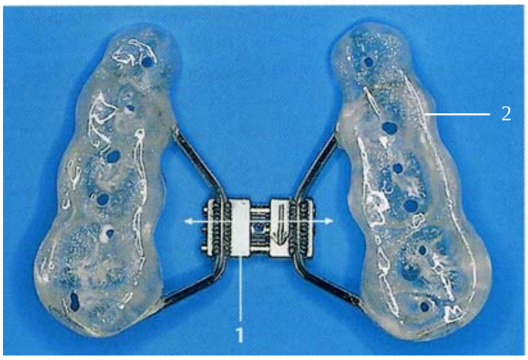


Fig 5 : Tooth Tissue-Borne Expander (Haas-Type).
1= jackscrew, 2= acrylic pad

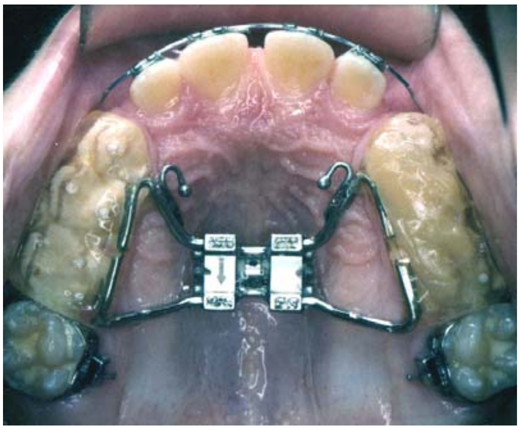


Fig 6: Patient treated by Haas-Type Expander.

The another type is the tooth-borne expander or Hyrax expander (Fig 7). This appliance consists of jackscrew (Hyrax®-screw) and four bands on the anchored teeth. It does not include the acrylic pad and presumably delivers the force to the maxilla only by means of the appliance-supporting teeth. This type of appliance is stated to have many advantages, ie. the good oral hygiene, greater comfort, and prevention of lesions on the palatal mucosa. In Polyclinic for Orthodontics (Poliklinik für Kieferorthopädie) at Ludwig Maximilian University of Munich, the Hyrax®-type expander is normally used. This appliance consists of Hyrax screw on the middle of the palate, metal framework joined to the four bands on anchored teeth (Fig 8).

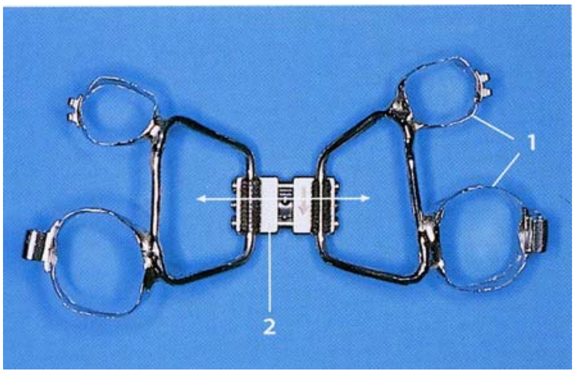


Fig 7: Tooth-borne (Hyrax®) Expander. 1 = Bands, 2 = Hyrax®-screw

Fig 8: Patient treated with rapid maxillary expander, before (left) and after (right) expansion.

Garib et al. [16] investigated the dentoskeletal effects of the two types of RME appliances, the tooth tissue-borne (Haas-type) and the tooth-borne (Hyrax® expander) by means of computed tomography (CT). All appliances were activated up to the full 7 mm capacity of the expansion screw. The results showed that the tooth tissue-borne (Haas-type) and tooth-borne (Hyrax®) provided a significant maxillary expansion and two types of these appliances produced similar orthopedic effects.

2.2.2 Indications of Rapid Maxillary Expander (RME)

The distinct indication for rapid maxillary expansion treatment is the transverse maxillary constriction. The constriction may be skeletal (narrow maxillary base or wide mandible), dental, or a combination of both skeletal and dental constriction. The easily recognizable clinical signs that could be the result of maxillary constriction are uni- or bilateral posterior crossbite and dental crowding[3,7,23]. Rapid maxillary expansion (RME) helps to expand the narrow palatal vault by opening the midpalatal suture, which widens the roof of the mouth and the floor of the nose. It is stated in many dental journals that this appliance used to be more effective as an adjunct to routine orthodontics to correct unilateral and bilateral posterior crossbites[23,24].

Dental crowding is another sign of maxilla discrepancy and/or the tooth-size arch-size discrepancies. The transverse expansion resulted from rapid maxillary expansion (RME) is an accepted procedure to relieve deficiencies in arch perimeter and/or length. This procedure is used not only to gain increased skeletal, but also to increase additional spaces in the dental arch. In addition, many orthodontists claimed that removal of teeth to resolve dental crowding problem worsen the profile appearance. In borderline dental crowding or patients with mild to moderate dental crowding, rapid maxillary expansion (RME) is the alternative effective treatment to provide sufficient arch spaces and to avoid future extractions in the orthodontic treatment [12,19,26]. McNamara (2006) [23] indicated, from long-term research that rapid maxillary expansion (RME) alone or combined with a removable mandibular appliance, when applied to corresponding patients, has shown to provide clinically significant increases in available arch.

In addition to resolving the discrepancy between tooth size and arch size, another phenomenon has occurred after the expansion of the maxilla: the “spontaneous correction” of mild Class II malocclusions. This is another treatment effect of the rapid maxillary expansion therapy. Normally, there is forward movement of the permanent mandibular first molars into the leeway space which improves the Class II malocclusion into Class I malocclusion in untreated patients. However, the shift in molar relationships in treated patients after the maxillary expansion therapy occurs before the transition from the mandibular second deciduous molars to the second premolars[23]. McNamara 2006 [23], manifested in an overview that his study groups observed a most interesting RME effect after the maxillary expansion of Class II patients in the early mixed dentition. They found the spontaneous correction in some Class II patients during the retention period. These patients had either as end-to-end or a full-cusp Class II molar relationship with reasonably well-balanced skeletal structures, characterized clinically as mild-to-moderate mandibular skeletal retrusion or an orthognathic facial profile, at the beginning of treatment. This phenomenon can be explained by disrupted occlusion after maxilla overexpansion of the patients. They appear to become more inclined to posture their jaws slightly forward. This can accordingly eliminate the tendency toward a buccal crossbite and improves the sagittal occlusal relationship. Presumably, subsequent mandibular growth makes this initial postural change permanent[3,12,23]. In conclusion, he indicated that RME is an efficient procedure to improve the molar relationship in some mild-to- moderate Class II malocclusion patients during the transition to the permanent dentition.

Furthermore, RME is currently indicated in such patients without crossbites. These patients often have laterally flared and tipped lingual cusps of maxillary posterior teeth below the occlusal plane with especially lingually tipped mandibular posterior teeth (Fig. 9). Even though it appears to be a normal posterior occlusion, the maxillary skeletal deficiency of these patients is camouflaged by the dentition. The functional occlusal interferences can often be detected in these patients; therefore, they are indicated for maxillary expansion therapy. The maxillary expansion will tip these buccally inclined maxillary molars further into the buccal musculature. The expansion of maxilla is needed to provide for the buccal movement to upright the lingually inclined mandibular molars[24].

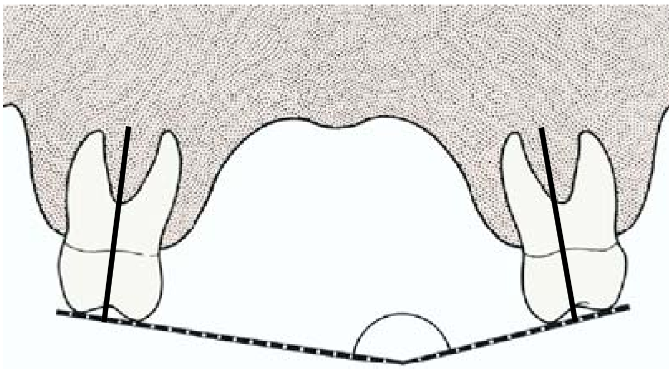


Fig 9: The tipped lingual cusps of the upper molar teeth.

Many orthodontists[7,12,20] suggest maxillary expansion therapy for patients with inadequate nasal capacity exhibiting chronic nasal respiratory problems (nasal stenosis). They are usually characterized by full-time mouth breathing and a constricted nasal aperture with the conchae literally compressed against the septum. The treatment effect of the maxillary expansion therapy, after opening of the midpalatal suture, results in greater nasal cavity and apical base gains, which improves nasal airflow and facilitates nasal breathing. Haas[9] found, in his RME experimental study on pigs, that the internasal width was increased after the maxillary expansion and the changes up to 7 mm was recorded. Hershey et al.[28] in 1976 found that RME corrected crossbites of subjects and provided a reduction in nasal resistance. He concluded that RME was an effective method to reduce nasal resistance from mouth breathing level to normal nasal respiration level. Furthermore, this study found that the reduction of nasal resistance was substantial and stable at least through the 3-month fixed-retention period.

The other indications for maxillary expansion therapy are the treatment of maxillary compression cases among cleft palate patients and antero-posterior maxillary discrepancy patients (all types of Class III malocclusion cases, both surgical and nonsurgical cases) who need not only transversal expansion of the maxilla, but also the sagittal expansion to improve into a more favorable relationship of the upper and lower denture bases. The opening of the midpalatal suture loosens the maxilla and facilitates the maxillary protraction. Haas [7,20] specified some of the advantages of palatal expansion that it results in a more favorable relationship of the denture bases in width and frequently in the anteroposterior plane and it creates more mobility to the maxilla (instead of teeth) for continued maxillary orthopedic protraction.

2.2.3 Treatment timing for RME

Many previous investigations have demonstrated that rapid maxillary expansion (RME) procedure is able to eliminate a transverse discrepancy between the dental arches due to maxillary constriction, which clinically shows as unilateral or bilateral crossbite. The biomechanical aspect of this expansion is to increase the upper arch transverse dimensions by separating of the two maxillary halves and opening the midpalatal suture.

Many authors[17,18,19,22] suggest that the sutural separation is most effective if accomplished prior to the completion of the pubertal growth spurt. This might be assumed at mixed dentition stage or early occlusal developmental phases of the patients. Melsen[31] studied the growth and maturation of the intermaxillary sutural system in order to evaluate the ideal treatment timing for maxillary transverse deficiency treatment. She used autopsy material to histologically examine the maturation of the mid-palatal suture at different development stages. From these histological data, she concluded that the orthopedic maxillary expansion treatment should be started at pre-adolescent stages of the patients. Furthermore, Baccetti et al[32] evaluated the treatment effect of rapid maxillary expansion before and after the pubertal peak in skeletal growth velocity. The study results showed that the treatment outcomes of rapid maxillary expansion treatment both in maxillary skeleton and circum-maxillary structures are more effective and more stable over the long term when approached during the early developmental phases. When the RME treatment after the pubertal growth spurt is performed, the maxillary adaptations to expansion therapy effect more on the dentoalveolar level than in the skeletal level.

Early rapid maxillary expansion treatment in the primary dentition is indicated in crossbite patients with functional mandibular shift. The objective of this early correction is to prevent mandibular dysfunction as well as to avoid possible development of craniofacial asymmetry. Bartzela T.[29] examined in early-treated and late-treated mixed dentition unilateral posterior crossbite patients and found that the early correction of crossbite has a positive influence on the further development of the maxilla and may prevent an abnormal transverse growth of the lower arch due to intermolar width. In addition, Proffit [18] indicated early expansion therapy for eliminating the functional occlusal problems, correcting the mandibular shift on closure and providing more space for the erupting maxillary teeth.

2.3 DENTAL EFFECTS ON UPPER AND LOWER DENTITION AS A RESULT OF RAPID MAXILLARY EXPANSION THERAPY

The treatment effect of rapid maxillary expansion therapy shows both in skeletal and dentoalveolar levels. The procedure has gained in popularity because of the relief of crowding, according to the increasing in dental arches dimensions. RME compensates for arch perimeter deficiencies through transverse expansion of the alveolar and dental arches. This procedure has been accepted to be one of the alternative treatments to gain additional spaces in dental arch to avoid teeth extraction in borderline dental crowding patients. Vargo J. et al [19] stated that the palatal expansion is an accepted method for increasing arch perimeter in early to mid-mixed dentition patients. They examined the treatment effects of the slow maxillary expansion with a bonded palatal expander on the upper arch. The study results showed that maxillary intercanine width increased significantly during treatment and partially relapsed posttreatment. The maxillary molar arch depth increased during treatment, and approximately 20% of this treatment increase was maintained posttreatment. In conclusion, they stated that the gain in arch perimeter (6-8%) is due to more increases in intermolar width (11-15%) than increases in arch depth (5%). The expansion resulted from this procedure was found greater in the posterior than anterior region.

The study of Adkin et al. [15] determined the relationships between transverse maxillary expansion and the resultant gain in arch perimeter in adolescent patients treated by Hyrax appliances. The dental casts of 21 adolescent patients were obtained before treatment and approximately 3 months after stabilization was used. The study results showed the increase in postexpansion changes in maxillary first molars, first premolars, canines widths and arch perimeter. Besides, arch length demonstrated a decrease during the period of study. They stated, in conclusion, that every millimeter of transpalatal width increase in the premolar region produces an increase in available maxillary arch perimeter.

Furthermore, there is also a dental effect on the lower arch dentition as a result of the expansion of the upper arch through RME therapy. McNamara in 2000[3] asserted his observation of the position of the lower dentition that the lower dentition may be influenced more by maxillary skeletal morphology than by the size and shape of the mandible. He also stated that there is not only the expansion of the maxillary dental arch following RME, but of the lower dental arch as well. This lower arch widening is due primarily to an uprighting of the lower posterior teeth, which often have erupted into occlusion in a more lingual orientation because of the associated constricted maxilla before RME treatment.

The another study of McNamara et al. [8] evaluated arch changes after Haas-typed RME and fixed appliances therapy through 20 age of years. They compared the dental arch dimensions between treated and untreated groups. At pretreatment, they found that both the maxillary and mandibular dental arches of the treated patients are narrower than that the corresponding dental arches of the subjects with untreated normal occlusion. They declared from their investigation that the treatment with RME followed by fixed appliances induced stable favorable increases in the width of the dental arches and arch depth. Moreover, they quoted the another study which is published in one chapter of the orthodontic textbook of the University of Michigan [36], that their investigation revealed a moderate increase in arch perimeter of treated subjects and a net decrease in the same measurement in untreated controls.

Geran R.G. et al. [22] evaluated the short-term and long-term changes in dental-arch dimensions in patients treated with acrylic splint rapid maxillary expander in the early mixed dentition followed by fixed appliances in the permanent dentition. They compared the dental cast measurement in two groups of consecutively treated patients and untreated control at 3 different times: pretreatment, after expansion and fixed appliance therapy, and at a long-term observation. The results showed an increase in dental arch perimeter and the maintenance was still observed in both dental arches at long-term observation. It can be assumed from this study that the treatment with an acrylic splint RME followed by fixed appliances produced significantly favorable short-term and long-term changes in almost all maxillary and mandibular arch measurements. In addition, it can be concluded that this expansion therapy is effective and stable for the treatment of constricted maxillary arches and can relieve the deficiencies in arch perimeter.

Moussa et al. in 1995 [26] evaluated 55 patients selected randomly from the practice of Andrew Haas, the developer of contemporary RME. The patients were treated with RME followed by fixed appliances. The dental casts were analyzed at three time intervals: pretreatment, posttreatment, and postretention. The results from this study showed the increase in maxillary intercanine and intermolar widths before and during treatment, the decrease in these widths after retention. Maxillary arch perimeter and arch length were also increased during treatment, followed by a decrease after retention. On the lower dental arch, the intercanine width increased at the end of treatment and decreased at postretention. On the other hand, the intermolar width increased during treatment and still increased after retention. The net decrease in the mandibular arch perimeter and arch length after retention were not statistically significant. In conclusion, the authors found good stability for maxillary intercanine width, maxillary and mandibular intermolar widths. There were small increases in arch perimeter and intercanine width which were still present in the long term.

The study of Lima A.C. et al. [35] involved a longitudinal investigation of the spontaneous arch dimension changes. Unlike the other published studies, the subjects of this study underwent only palatal expander without subsequent orthodontic intervention. The measurements of dental casts were made at the 4 assessment stages: pre-expansion, short-term follow-up, progress, and long-term follow up. The mandibular arch dimension changes from this study, were found that the net gain changes of intermolar width showed an increase which was derived from the molar slight uprighting. They found no change in intercanine width after RME. For the mandibular arch length and arch perimeter, from this study, they did not show any changes that were attributable to RME. They concluded from their investigation, that there was remarkable and positive clinical stability in intermolar width and intercanine width, indicating that the increase in the mandibular arch width dimension was in response to the orthopedic effects of rapid palatal expansion in the early and mid-mixed dentition.

Handelman C.S. et al [34] compared transarch widths of the maxilla between three groups of children and adult patients using Haas expanders and untreated control adult group. The result showed the similar mean transarch widths increase in the maxilla in both treated groups for the molars and the second premolars. The expanded treated groups had a greater increase, observed from the control-untreated group. The transarch widths in mandible in children and adult treated groups showed expansion changes from pretreatment to posttreatment which were small and not clinically significant. The transarch widths after out of retention period, also showed a decrease in these widths, but this narrowing was not statistically significant.

The study of Zafer S. et al. [17] compared the dentoskeletal effects of a modified acrylic-bonded maxillary expansion between mixed and permanent dentitions. They studied the lateral, frontal cephalograms and upper dental casts before treatment, after treatment and after retention. The result this study showed that, the upper intercanine and intermolar widths were increased significantly with treatment. In the permanent dentition group, this increase was more stable than the mixed dentition group until the follow-up after retention because the relapse tendencies in mixed dentition group showed more reduction than did the permanent dentition group. From this investigation, they stated the suggestion from the results that orthopedic effects of RME are not as great as expected at early ages, and it might be a better alternative to delay RME to early permanent dentition.

3. METHODOLOGY

3.1 Study design

This investigation is a retrospective study.

3.2 Study population

Treated samples:

Thirty-two patients, 13 males and 19 females, who underwent rapid maxillary expansion therapy (Hyrax®-type expander), followed by routine orthodontic fixed appliance treatment in the Graduate Orthodontic Clinic at Polyclinic for Orthodontics (Poliklinik für Kieferorthopädie), Ludwig Maximilian University of Munich, were selected, according to the following criteria:

- 3.2.1 No history of previous orthodontic and orthopedic treatments
- 3.2.2 No craniofacial anomalies or syndromes
- 3.2.3 No missing teeth in the upper and lower dental arches
- 3.2.4 Patients with maxillary constriction
- 3.2.5 Angle Class II malocclusion
- 3.2.6 All patients treated by nonextraction therapy during mixed dentition stage

Untreated samples:

Thirty-two children, 13 males and 19 females, who have mixed dentition at the beginning of the observation period, were selected based on the same criteria applied to the treated samples with the exception of maxillary constriction.

A total of 64 samples divided into male and female groups were shown in Table 1.

Subject	Males	Females	Total
RME patients (treated samples)	13	19	32
Control (untreated samples)	13	19	32
Total	26	38	64

Table 1 : Sample populations

3.3 Methods

3.3.1 Orthodontic procedures

The patients underwent Hyrax-type rapid maxillary expanders (Hyrax expander screw, Forestadent®, Germany) banded on anchored teeth. The arms of the expansion screw were soldered to the bands that were fitted on maxillary first permanent molars, maxillary first permanent premolars or deciduous canines. The hyrax device was centered at the maxillary arch. The appliance was activated one-quarter turn twice a day. Each activation was equal to 0.25 mm. The patients were seen at weekly intervals for approximately 3 weeks until the desired overcorrection for each patient was achieved. This expansion was considered adequate when the occlusal aspect of the maxillary lingual cusp of upper first molars contacted the occlusal aspect of the buccal cusp of the mandibular lower first molars. The expander was left in situ during the expansion and stabilization period for a mean time of 6 months. After the removal of RME appliance, the simple palatal plate or transpalatal arch bar was placed for the late mixed dentition patients until all of the permanent teeth were erupted, then the comprehensive non-extraction orthodontic fixed appliance treatments were performed.

3.3.2 Dental casts measurement

A total of 128 dental casts for the dental arch dimension measurements, were selected from a group of patients treated by rapid maxillary expander followed by orthodontic fixed appliance and a group of untreated children at different observation periods.

The treated samples consisted of 64 upper and lower dental casts of 32 patients, obtained at 4 assessment stages: pre-treatment (T1), after expansion and during orthodontic treatment (T2), post treatment at the end of fixed appliance (T3) and at post retention (T4). The mean ages of female and male treated group at assessment stages are shown in Table 2. The mean age at T1 for treated group was 9 years 3 months ± 1 year 6 months, 11 years 8 months ± 1 year 7 months at T2, 13 years 11 months ± 1 year 3 months at T3 and 15 year 4 months ± 1 year 4 months at T4 (Table 3).

	N	Age Range (year)	Mean (year)	Std. Deviation
Treated group - *Females*				
Pre-treatment (T1)	19	7.2-12.1	9.24	1.14
After expansion (T2)	19	9.7-13.3	11.45	1.28
Post-treatment (T3)	19	10.9-16.1	13.86	1.32
Post-retention (T4)	19	11.8-17.6	15.25	1.38
Treated group - *Males*				
Pre-treatment (T1)	13	6.2-12.9	9.2	1.92
After expansion (T2)	13	8.0-14.6	11.95	1.83
Post-treatment (T3)	13	12.3-16.3	14.08	1.18
Post-retention (T4)	13	13.1-17.8	15.35	1.25

Table 2 : Descriptive statistics of female and male treated groups: the distribution, age range, average age and standard deviation (SD).

	N	Age Range (year)	Mean (year)	Std. Deviation
Treated group				
Pre-treatment (T1)	32	6.2-12.9	9.22	1.48
After expansion (T2)	32	8.0-14.6	11.66	1.52
Post-treatment (T3)	32	10.9-16.3	13.95	1.25
Post-retention (T4)	32	11.8-17.8	15.29	1.31

Table 3 : Descriptive statistics of treated group: the distribution, age range, average age and the standard deviation (SD).

The mean duration of the T1 to T2 (pre-treatment to after expansion and during orthodontic treatment), T2 to T3 (after expansion and during orthodontic treatment to end of fixed appliances treatment) and T3 to T4 (end of fixed appliances treatment to post retention) for treated group, were 2 years 7 months ± 8 months, 2 years 6 months ± 1 year 7 months, 2 year 1 month ± 1 year 1 month, respectively (Table 4).

Duration period (year, month)	N	T1 – T2		T2 – T3		T3 – T4	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Treated group	32	2,7	0,8	2,6	1,7	2,1	1,1
Untreated group	32	2,5	0,9	2,4	0,11	2,2	1,0

Table 4 : Descriptive statistics of the duration between each observation period of treated and untreated groups: the distribution, and standard deviation in year and month.

The untreated samples consisted of 64 upper and lower dental casts of 32 children, obtained at 4 observation periods: first observation period (T1), second observation period (T2), third observation period (T3), and fourth observation period (T4). Most of the children had mid-mixed dentition at T1, late-mixed dentition at T2 and permanent dentition at T3,T4 which resemble to the treated group at each time that records were taken. The mean ages of female and male untreated group at 4 observation stages is showed in Table 5. The mean age at T1 for untreated group was 9 years 5 months ± 1 year, 10 years 11 months ± 11 months at T2, 13 years 7 months ± 11 months at T3 and 15 year 2 months ± 1 year at T4 (Table 6).

	N	Age Range (year)	Mean (year)	Std. Deviation
Untreated group - Females				
First observation period (T1)	19	8.0-10.9	9.43	0.92
Second observation period (T2)	19	10.0-12.9	10.76	0.94
Third observation period (T3)	19	12.1-14.1	12.18	0.97
Fourth observation period (T4)	19	13.8-15.3	13.68	0.88
Untreated group - Males				
First observation period (T1)	13	6.9-11.0	9.4	1.23
Second observation period (T2)	13	10.5-12.7	11.25	0.82
Third observation period (T3)	13	12.9-14.2	13.16	0.56
Fourth observation period (T4)	13	14.3-16.3	14.91	0.72

Table 5 : Descriptive statistics of female and male untreated groups: the distribution, age range, average age and standard deviation.

	N	Age Range (year)	Mean (year)	Std. Deviation
Untreated group				
First observation period (T1)	32	6.9-11.0	9.42	1.04
Second observation period (T2)	32	10.0-12.9	10.96	0.91
Third observation period (T3)	32	12.1-14.2	13.58	0.95
Fourth observation period (T4)	32	13.8-16.3	15.18	1.01

Table 6 : Descriptive statistics of untreated group: the distribution, age range, average age and the standard deviation.

The mean duration of the T1 to T2 (first to second observation period), T2 to T3 (second to third observation period) and T3 to T4 (third to fourth observation period) for treated group, was 2 years 5 months ± 9 months, 2 years 4 months ± 11 months, 2 years 2 months ± 1 year, respectively (Table 4).

Measurements were made directly on upper and lower dental casts by one investigator with an electronic digital caliper with sharpened tips (Fig 10), recorded accurate to 0.01 mm. The dental arch dimensions were recorded on the occlusal and palatal/lingual aspects, i.e. arch depth, intercanine width, interpremolar width, intermolar width, transarch (transpalatal) widths of canines, premolars and molars teeth, arch length, arch perimeter, overjet and overbite. The reference points for the measurements were marked using the sharp pointed pencil to establish the exact landmark points. If the cusp tips were worn, the centers of the resulting facets were used as landmarks.

Fig 10 : Instrument for dental cast measurement : an electronic digital caliper.

The following measurements were performed:

Upper dental arch measurements *(Fig 11,12)*

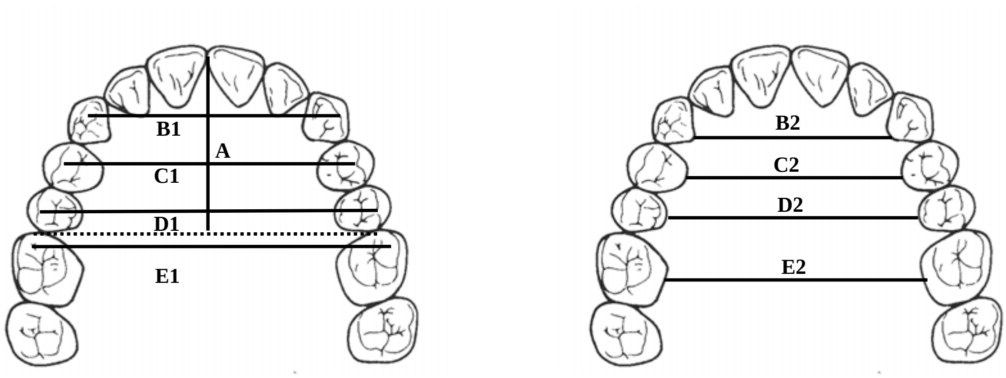


Fig 11 : The upper dental arch measurements, A=Total arch depth, B1= Intercanine width, B2=Caninetransarch width, C1=Interfirstpremolar width, C2=Firstpremolartransarch width , D1= Intersecondpremolar width, D2=Secondpremolartransarch width, E1=Intermolar width, E2=Molartransarch width

1. *Total arch depth (A)* : The perpendicular distance from the contact point between maxillary central incisors to a line constructed between the mesial contact points of the maxillary first molars and the distal contact points of second deciduous molars/ second permanent premolars.
2. *Intercanine width (B1) , Caninetransarch width (B2)*
   - 2.1 Intercanine width (B1) : Distance between the cusp tips of the right and left maxillary deciduous /permanent canines.
   - 2.2 Caninetransarch width (B2) : Distance between the most lingual points of a tooth to the like point of the right and left maxillary deciduous/permanent canines.
3. *Interfirstpremolar width (C1), Firstpremolartransarchwidth (C2)*
   - 3.1 Interfirstpremolar width (C1) : Distance between the buccal cusp tips of the right and left maxillary deciduous first molars- /permanent first premolars.

3.2 Firstpremolartransarch width (C2) : Distance between the most lingual points of a tooth to the like point of the right and left maxillary deciduous first molars/permanent first premolars.

4. *Intersecondpremolar width (D1), Secondpremolartransarch width (D2)*

4.1 Intersecondpremolar width (D1) *:* Distance between the buccal cusp tips of the right and left maxillary deciduous second molars/ permanent second premolars.

4.2 Secondpremolartransarch width (D2) : Distance between the most lingual points of a tooth to the like point of the right and left maxillary deciduous second molars/permanent second premolars.

5. *Intermolar width (E1), Molartransarch width (E2)*

5.1 Intermolar width (E1) : Distance between the mesiobuccal cusp tips of the right and left maxillary first permanent molars.

5.2 Molartransarch width (E2) : Distance between the most lingual points of a tooth to the like point of the right and left maxillary first permanent molars.

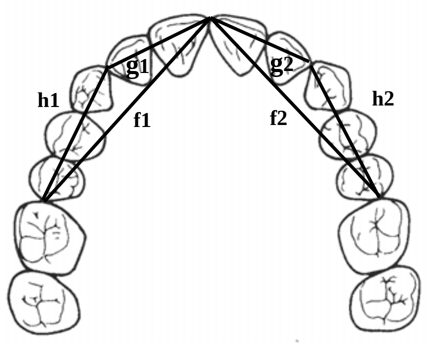


Fig 12 : The upper dental arch measurements, f1=arch length on the right side, f2 = arch length on the left side, g1= anterior segment on the right side, g2= anterior segment on the left side, h1=posterior segment on the right side, h2= posterior segment on the left side

6. *Arch length (F= f1+f2)* : Total of left and right absolute distances from the contact point between maxillary central incisors to the mesial contact points of maxillary first molars.
7. *Arch perimeter (G+H)*
   - 7.1 *Anterior segments (G= g1+g2)* : Total of left and right absolute distances between the contact point of maxillary central permanent incisors and the contact points between the deciduous/permanent lateral incisors and deciduous/permanent canines.
   - 7.2 *Posterior segments (H= h1+h2)* : Total of left and right absolute distances between the contact points of the maxillary deciduous/permanent lateral incisors and deciduous/permanent canines and that between the maxillary deciduous second molars/permanent second premolars and first permanent molars.
8. *Overjet* : Horizontal distance from the labial surface of the maxillary central incisors to the labial surface of the mandibular central incisors measured parallel with the occlusal plane.
9. *Overbite* : Amount of vertical overlap of the maxillary and mandibular central incisors measured perpendicular to the occlusal plane; openbite was assigned a negative value.

Lower dental arch measurements (Fig 13,14)

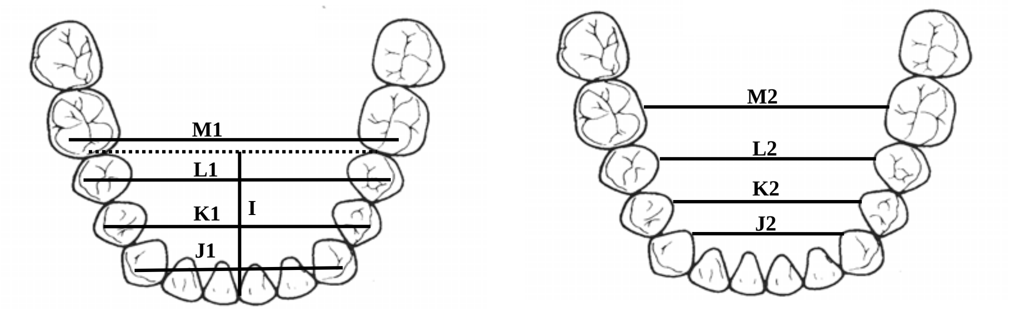


Fig 13 : The lower dental arch measurements, I=Total arch depth, J1=Intercanine width, J2=Caninetransarch width, K1=Inter-firstpremolar width, K2=Firstpremolartransarch width , L1= Intersecondpremolar width, L2=Secondpremolarltransarch width, M1=Intermolar width, M2=Molartransarch width

1. *Total arch depth (I)* : The perpendicular distance from the contact point between mandibular central incisors to a line constructed between the mesial contact points of the first molars and the distal contact points of second deciduous molars/second permanent premolars.
2. *Intercanine width (J1)*, *Caninetransarch width (J2)*
   2.1 Intercanine width (J1) : Distance between the cusp tips of the right and left mandibular deciduous/permanent canines.
   2.2 Caninetransarch width (J2) : Distance between the most lingual points of a tooth to the like point of the right and left mandibular deciduous/permanent canines.
3. *Interfirstpremolar width (K1), Firstpremolartransarch width (K2)*
   3.1 Interfirstpremolar width (K1) : Distance between the buccal cusp tips of the right and left mandibular deciduous first molars/ permanent first premolars.
   3.2 Firstpremolartransarch width (K2) : Distance between the most lingual points of a tooth to the like point of the right and left mandibular deciduous first molars/permanent first premolars.

4. *Intersecondpremolar width (L1), Secondpremolartransarch width (L2)*

4.1 Intersecondpremolar width (L1) *:* Distance between the buccal cusp tips of the right and left mandibular deciduous second molars/permanent second premolars.

4.2 Secondpremolartransarch width (L2) : Distance between the most lingual points of a tooth to the like point of the right and left mandibular deciduous second molars/permanent second premolars.

5. *Intermolar width (M1), Molartransarch width (M2)*

5.1 Intermolar width (M1) : Distance between the mesiobuccal cusp tips of the right and left mandibular first permanent molars.

5.2 Molartransarch width (M2) : Distance between the most lingual points of a tooth to the like point of the right and left mandibular first permanent molars.

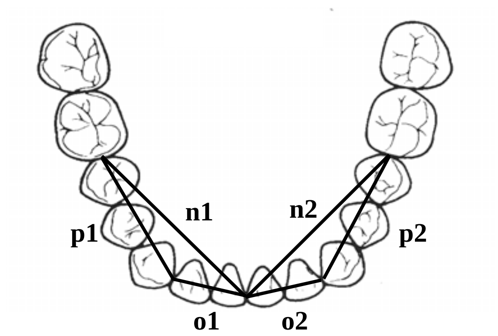


Fig 14 : The lower dental arch measurements, n1=arch length on the right side, n2 = arch length on the left side, o1= anterior segment on the right side, o2= anterior segment on the left side, p1=posterior segment on the right side, p2= posterior segment on the left side

6. Arch length (N= n1+n2) : Total of left and right absolute distances from the contact points between central incisors to mesial contact points of the mandibular first molars.

7. Arch perimeter (O+P)
   7.1 Anterior segments (O=o1+o2) : Total of left and right absolute distances between the contact points of the mandibular central permanent incisors and the contact points between the deciduous/permanent lateral incisors and deciduous/permanent canines.
   7.2 Posterior segments (P=p1+p2) : Total of left and right absolute distances between the contact points of the mandibular deciduous/permanent lateral incisors and deciduous first molars /permanent canines and that between the deciduous second molars/permanent second premolars and first molars.

3.4 Statistics

3.4.1 Method error

To standardize measurements, all data were collected by one investigator. All measurements at the same position were recorded 3 times. The mean of these 3 values was collected for each measurement. The measurements were repeated on 10 randomly selected casts after a one-week interval to determine error of the method between first and second measures. The original and repeated measurements were compared with paired *t*-test to examine for the error of the method.

3.4.2 Statistical analysis

All data analyses were performed using the SPSS® statistical software program (version 15.0 for Windows, SPSS® Inc., Chicago, Illinois, USA)

Descriptive statistics, mean and standard deviation, was calculated for all of the measurements.

The normality of the distribution was verified for all variables by the Kolmogorov-Smirnoff test.

The comparisons of the variables within treated group between the different treatment times were statistically analyzed, using paired *t*-test, with a significance level of $P<0.05$.

The statistical analyses, Student *t* test for independent samples with a significance level of $P<0.05$, was performed to analyze and to determine the differences of the measurement values between treated and untreated groups whether these changes were significantly different at different time periods.

The following statistical comparisons were performed:

- Comparison of pre-treatment forms of the upper and lower dental arches at the beginning (T1): Treated group at pretreatment stage compared to untreated group at first observation period.
- Evaluation of treatment effect after RME therapy: Difference between pre-treatment and after expansion and during orthodontics fixed appliance (T2-T1 changes) in treated group compared to the difference between first and second observation time periods (T2-T1 changes) in untreated group.
- Evaluation of treatment effect after fixed orthodontics appliance therapy: Difference between pre-treatment and at the end of fixed orthodontics appliance therapy (T3-T1 changes) in treated group compared to the difference between first and third observation time periods (T3-T1 changes) in untreated group.
- Evaluation of posttreatment changes: Difference between post treatment at the end of fixed appliances treatment and postretention (T4-T3 changes) in treated group compared to the difference between third and fourth observation time periods (T4-T3 changes) in untreated group.
- Evaluation of overall changes: Difference between pre-treatment and postretention (T4-T1 changes) in treated group compared to the difference between first and fourth observation time periods (T4-T1 changes) in untreated group.
- Comparison of final forms of the upper and lower dental arches at long-term period (T4): Treated group at postretention compared to untreated group at fourth observation period.

4. RESULTS

4.1 Method error

The method error of the measurement was calculated using paired *t*-test by comparing the original and one-week-repeated measurements. From these two measurements, standard deviations were found to be in the range of 0.08 to 0.18 which was considered no clinically significant. In addition, there was no statistically significant difference between the two measurements at $P<0.05$.

4.2 Normality of the sample groups

The normal distribution of the two sample groups for all variables was calculated using the Kolmogorov-Smirnoff test. The analyzed statistic showed no significant difference at $P<0.05$. Therefore, the parametric statistical tests; i.e. paired *t*-test for within-case dependent samples and student *t*-test for between-case independent samples, were selected for the statistical analysis.

4.3 The difference of distribution between males and females

All of the measurements between males and females samples within the treated and untreated groups, were analyzed using student *t*-test for independent samples. It was found that there was no statistically significant difference at all of the assessment stages between males and females within the two samples groups at $P<0.05$.

4.4 The effect of rapid maxillary expansion therapy in treated group

Maxillary Arch:

Descriptive statistics of the upper dental arch measurements of the treated group at 4 assessment stages: pre-treatment (T1), after expansion and during orthodontic treatment (T2), post treatment at the end of fixed appliances treatment (T3) and at post retention (T4), are shown showed in Table7 and Fig 15-21.

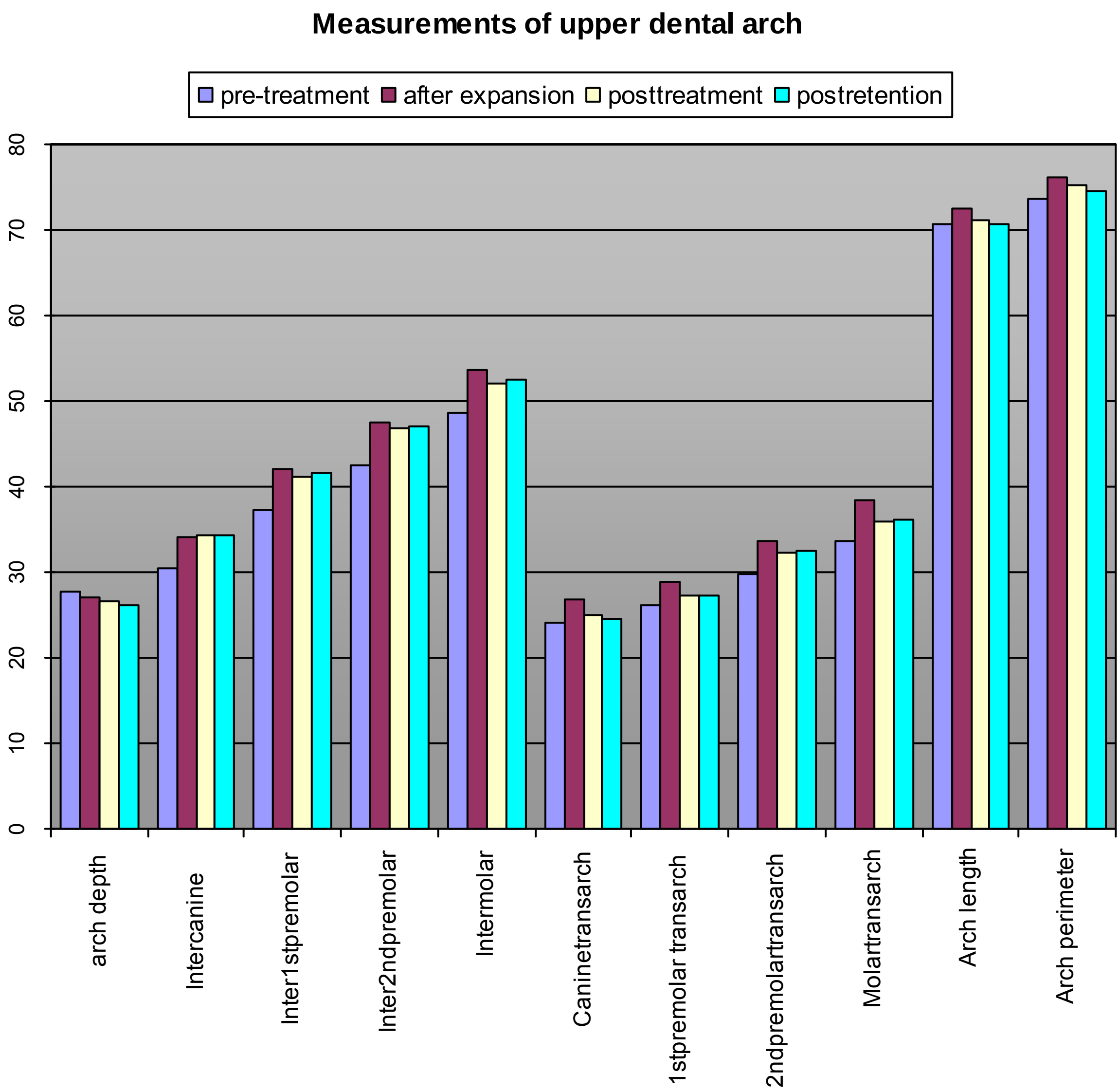


Fig 15 : Measurements of maxillary dental arch of treated patient samples at four assessment stages.

	Pre-treatment (T1)		After expansion (T2)		Post treatment (T3)		Post retention (T4)		P Value					
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	T1/T2	T1/T3	T1/T4	T2/T3	T2/T4	T3/T4
Maxillary dental arch														
Total arch depth	27.82	2.80	27.00	2.46	26.53	2.37	26.03	2.46	*	*	*	NS	*	*
Dental arch width (occlusal)														
Intercanine	30.51	2.17	34.07	2.03	34.28	2.11	34.30	2.03	*	*	*	NS	NS	NS
Interfirstpremolar	37.26	2.47	42.01	2.44	41.24	2.45	41.50	2.44	*	*	*	*	*	NS
Intersecondpremolar	42.48	2.98	47.57	2.48	46.87	2.56	47.15	2.48	*	*	*	*	NS	NS
Intermolar	48.71	3.15	53.54	2.69	51.98	3.02	52.50	2.69	*	*	*	*	*	*
Dental transarch width (palatal)														
Caninetransarch width	24.07	2.24	26.76	1.56	24.97	1.53	24.48	1.56	*	*	NS	*	*	*
Firstpremolartransarch width	26.08	1.97	28.84	1.50	27.26	1.47	27.38	1.50	*	*	*	*	*	NS
Secondpremolartransarch width	29.84	2.15	33.57	1.65	32.29	1.78	32.55	1.65	*	*	*	*	*	NS
Molartransarch width	33.64	2.44	38.47	2.36	35.99	2.24	36.16	2.36	*	*	*	*	*	NS
Arch length	70.79	4.78	72.56	4.47	71.25	4.56	70.69	4.47	*	*	NS	*	*	*
Arch perimeter	73.60	4.56	76.20	4.68	75.28	4.91	74.61	4.68	*	*	*	*	*	*
Overjet	3.61	1.83	2.94	0.78	2.17	0.76	2.30	0.78	NS	*	*	*	NS	NS
Overbite	2.60	2.10	2.55	0.84	2.25	0.94	2.19	0.84	NS	*	*	NS	NS	NS

*P>.05; NS = not significant

Table 7 : Descriptive statistics of treated group on maxillary dental arch: the mean averages of the measurements, the standard deviation (SD) and statistical significance (P value) at four assessment stages.

Arch Depth:

The maxillary dental arch depth of the treated sample group decreased along the assessment time periods from T1 to T4. It decreased significantly (P<.05) from T1 to T2, from T3 to T4 and decreased non-significantly (P<.05) from T2 to T3 (Fig 15,16).

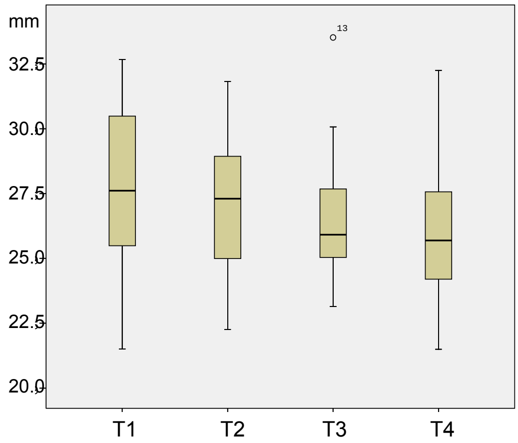


Fig 16 : Box-plots of maxillary arch depth measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Dental Arch Width:

In contrast with arch depth, the intercanine width showed the increase during the assessment stages from T1 to T4. From T1 to T2, the increase is statistically significant (P<.05), but this increase is not statistically significant (P<.05) from T2 to T4 (Fig 15,17).

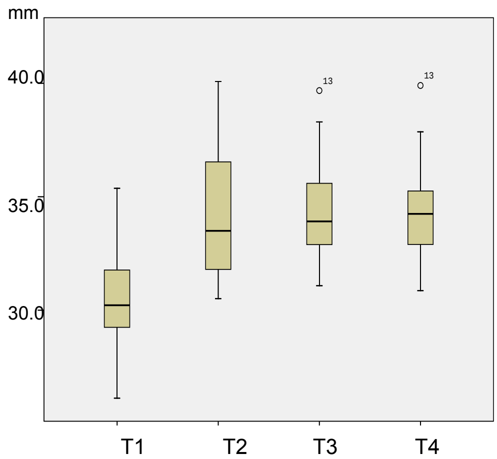
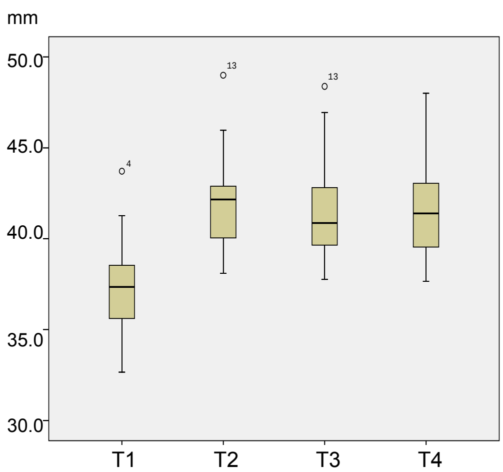
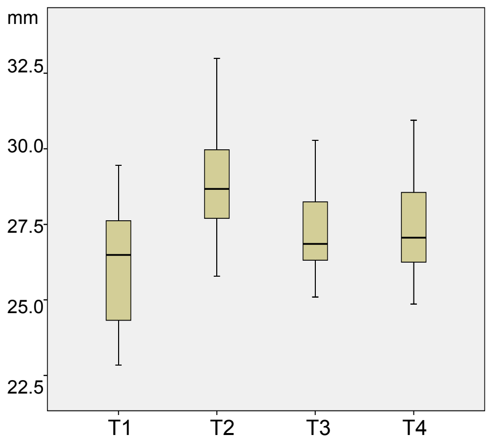


Fig 17 : Box-plots of maxillary intercanine occlusal width measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Interfirstpremolar-, Intersecondpremolar-, and Intermolar widths (occlusal), firstpremolar transarch-, secondpremolar transarch-, and molartrasarch widths (palatal), showed the increase of the values from T1 to T2, followed by the decrease of the values from T2 to T3, and the increase of the values from T3 to T4, respectively. Most of these values from T3 to T4 increased statistically non-significant (P<.05), except the intermolar (occlusal) width (Fig 15,18).



Interfirstpremolar width



firstpremolartransarch width

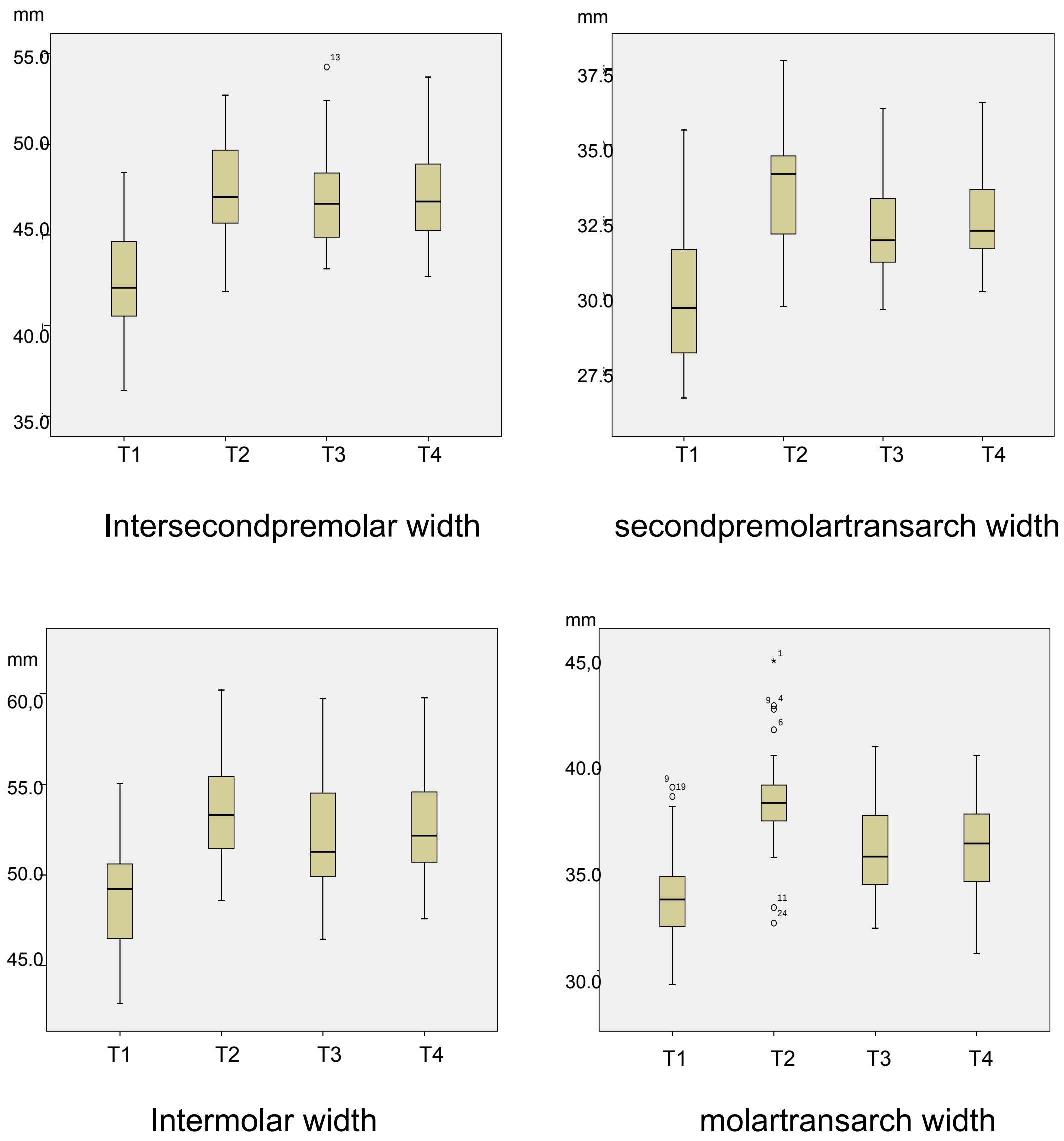


Fig 18 : Box-plots of maxillary interpremolar, intermolar, premolartransarch, molartransarch widths measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

The statistically significant increase (P<.05) of caninetransarch width(palatal) was found from T1 to T2, but the statistically significant decrease (P<.05) was found from T2 to T4 (Fig 15,19).

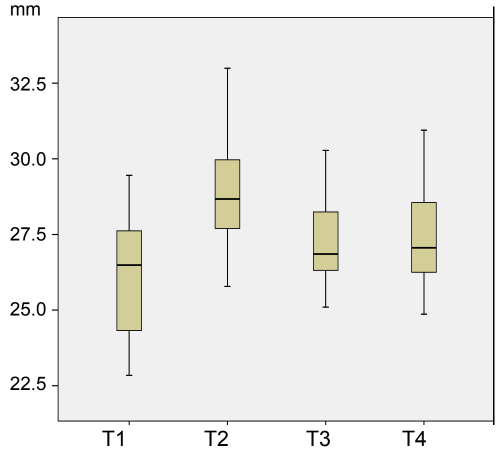


Fig 19 : Box-plots of maxillary caninetransarch width measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Arch Length and Arch Perimeter:

Arch length and arch perimeter presented the statistically significant ($P<.05$) increase at the beginning of assessment stage from T1 to T2 and the statistically significant ($P<.05$) decrease after the expansion to postretention assessment stages; from T2 to T4 (Fig 15,20).

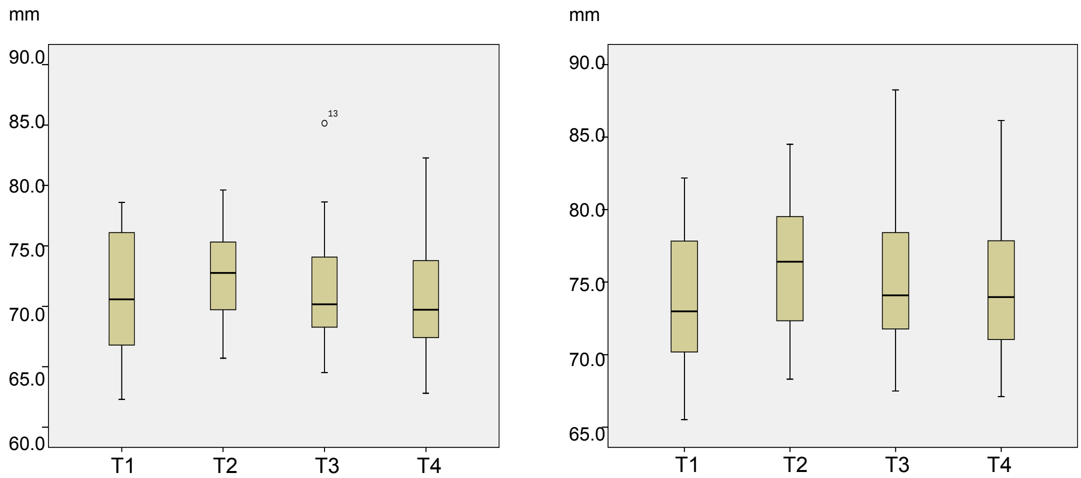


Fig 20 : Box-plots of maxillary arch length and perimeter measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Overjet, Overbite:

The decrease of overjet showed from T1 to T3 and the increase from T3 to T4, only the decrease from T2 to T3 showed the statistically significant (P<.05). The overbite decreased non-statistically significant (P<.05) from T1 to T4 (Fig 21).

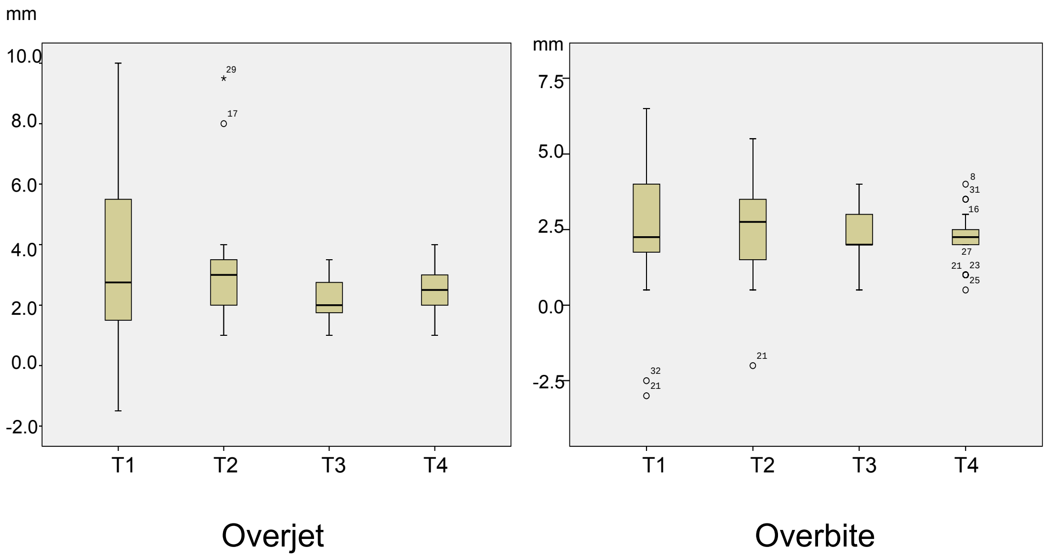


Fig 21 : Box-plots of overjet and overbite measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Mandibular Arch:

Descriptive statistics for the lower dental arch measurements of the treated group at 4 assessment stages: pre-treatment (T1), after expansion and during orthodontic treatment (T2), post treatment at the end of fixed appliance treatment (T3) and at post retention (T4), are shown in Table 8 and Fig 22-27.

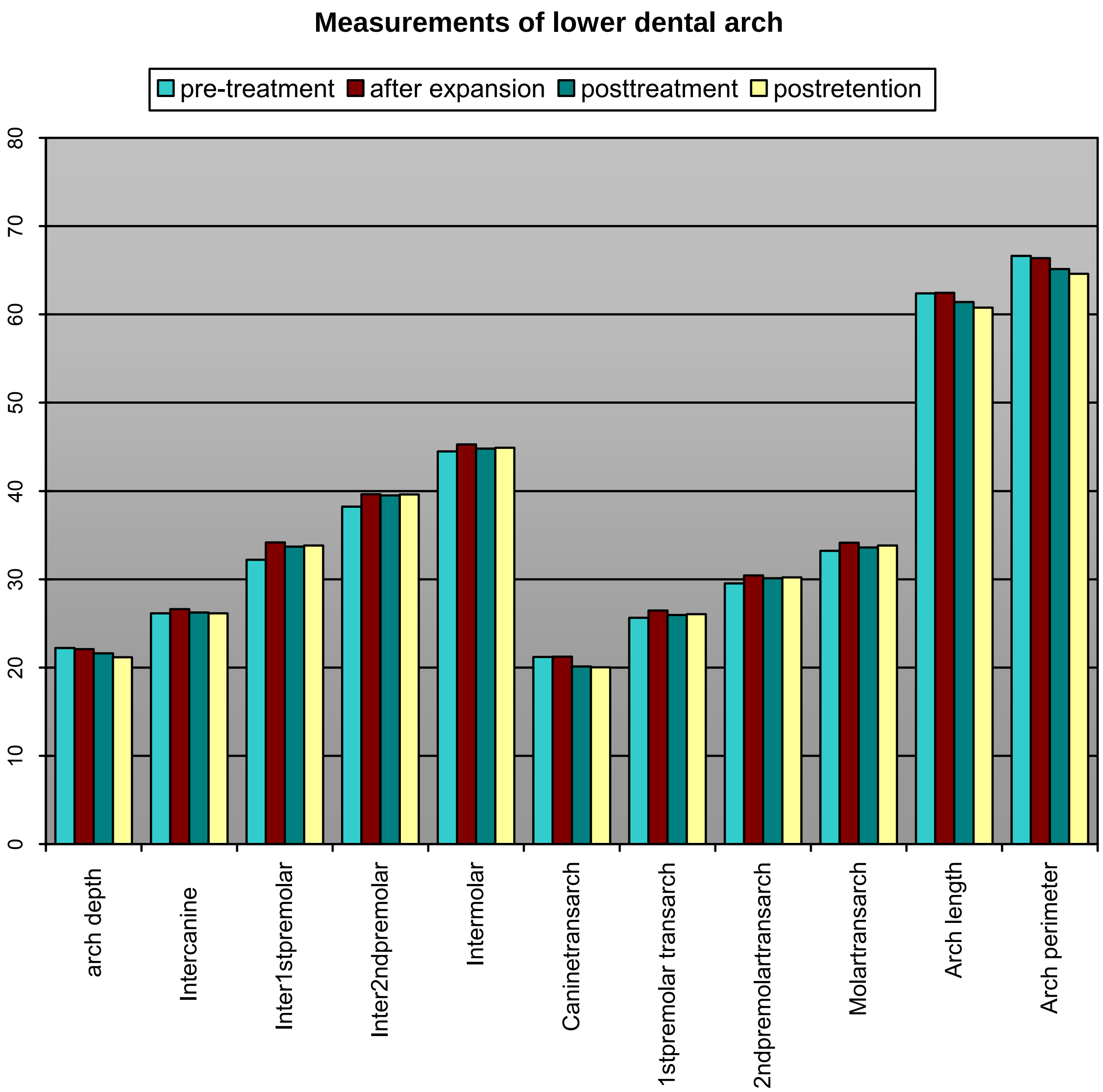


Fig 22 : Measurements of mandibular dental arch of treated patient samples at four assessment stages.

	Pre-treatment (T1)		After expansion (T2)		Post treatment (T3)		Post retention (T4)		P Value					
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	T1/T2	T1/T3	T1/T4	T2/T3	T2/T4	T3/T4
Mandibular dental arch														
Total arch depth	22.22	1.70	22.09	1.99	21.59	2.09	21.15	1.91	NS	*	*	NS	*	*
Dental arch width (occlusal)														
Intercanine	26.13	1.63	26.60	2.25	26.23	1.82	26.12	2.02	*	NS	NS	NS	*	NS
Interfirstpremolar	32.21	2.37	34.16	2.39	33.69	2.01	33.81	2.12	*	*	*	*	NS	NS
Intersecondpremolar	38.20	2.27	39.65	2.95	39.47	2.46	39.62	2.45	*	*	*	*	NS	NS
Intermolar	44.48	2.88	45.26	2.74	44.79	2.46	44.88	2.56	*	NS	NS	*	NS	NS
Dental transarch width (lingual)														
Caninetransarch width	21.20	1.90	21.20	1.91	20.12	1.23	20.02	1.35	NS	*	*	NS	*	NS
Firstpremolartransarch width	25.61	1.89	26.46	1.82	25.93	1.48	26.04	1.52	*	NS	NS	*	NS	NS
Secondpremolartransarch width	29.50	2.08	30.43	2.22	30.12	1.64	30.21	1.81	*	NS	*	*	NS	NS
Molartransarch width	33.20	2.10	34.12	2.06	33.61	1.99	33.81	2.12	*	NS	*	*	NS	NS
Arch length	62.37	2.98	62.44	3.69	61.40	3.97	60.78	3.69	NS	NS	*	*	*	*
Arch perimeter	66.38	3.60	66.62	4.03	65.14	4.27	64.58	4.10	NS	*	*	*	*	*

*P>.05; NS, not significant

Table 8 : Descriptive statistics of treated group on mandibular dental arch: the mean averages of the measurement and the standard deviation (SD) and statistical significance (P value) at four assessment stages.

Arch Depth:

The mandibular dental arch depth of the treated samples group decreased along the assessment time periods from T1 to T4. It decreased non-significantly (P<.05) from T1 to T3 and decreased statistically significantly (P<.05) from T3 to T4 (Fig 22,23).

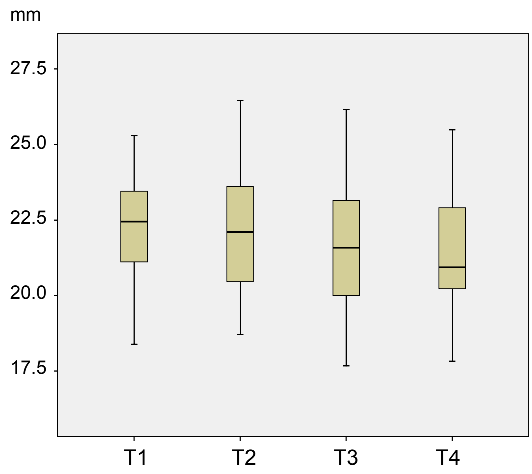


Fig 23 : Box-plots of mandibular arch depth measured at pretreatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Dental Arch Width:

The intercanine width showed the significant increase from T1 to T2 and the decrease from T2 to T4. The decrease of the intercanine width from T2 to T4 was not statistically significant (P<.05) (Fig 22,24).

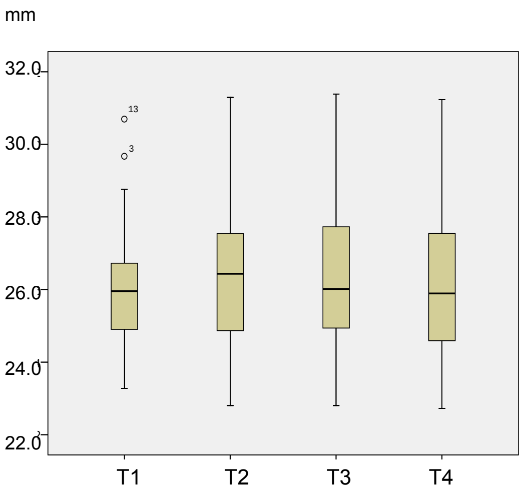
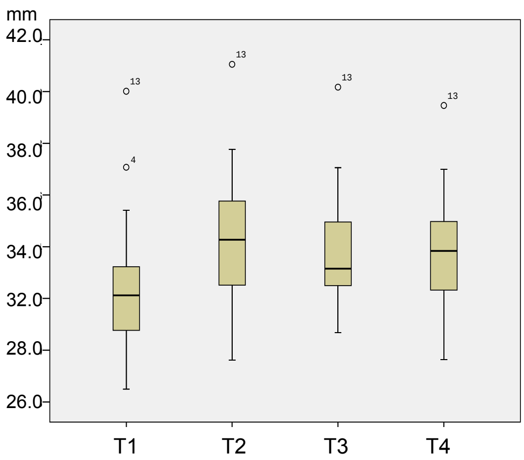
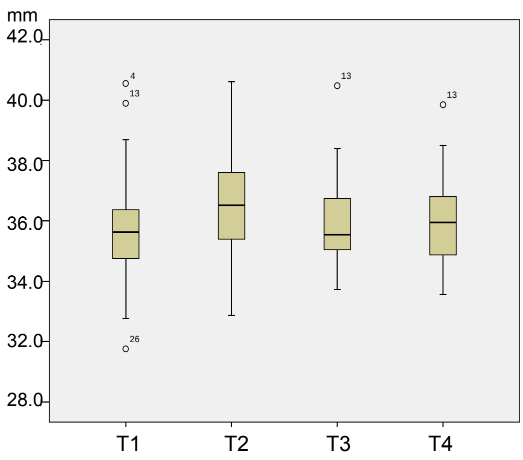


Fig 24 : Box-plots of mandibular intercanine occlusal width measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Interfirstpremolar-, Intersecondpremolar-, and Intermolar widths (occlusal), first- premolartransarch-, secondpremolar transarch-, and molartransarch widths (palatal), increased significantly (P<.05) from T1 to T2. The values decreased significantly from T2 to T3, and followed by the increase from T3 to T4 which was not statistically significant (P<.05) (Fig 22,25).



Interfirstpremolar width



firstpremolartransarch width

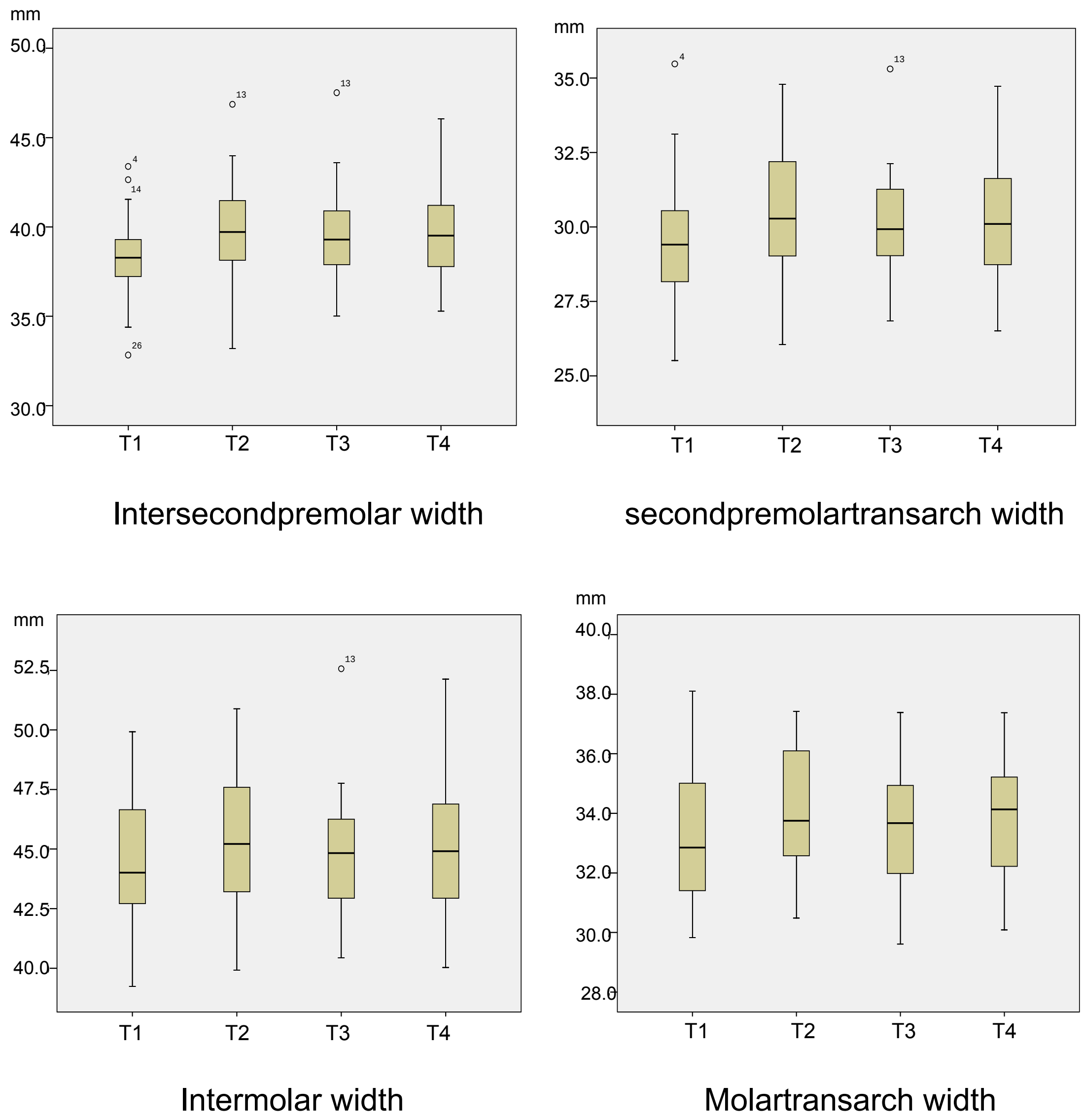


Fig 25 : Box-plots of mandibular interpremolar, intermolar, premolar-transarch, molartransarch widths measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Caninetransarch width (palatal) maintained from T1 to T2. It was decreased through the following assessment stages from T2 to T4 (Fig 22,26).

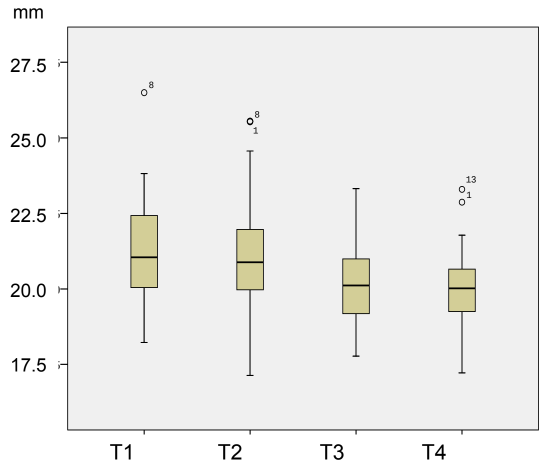


Fig 26 : Box-plots of mandibular caninetransarch width measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

Arch Length and Arch Perimeter:

The increase of arch length and arch perimeter was found from at the beginning of the treatment (T1) to after expansion and during orthodontic fixed appliances (T2). The significant decrease (P<.05) was found from T2 to T4 (Fig 22,27).

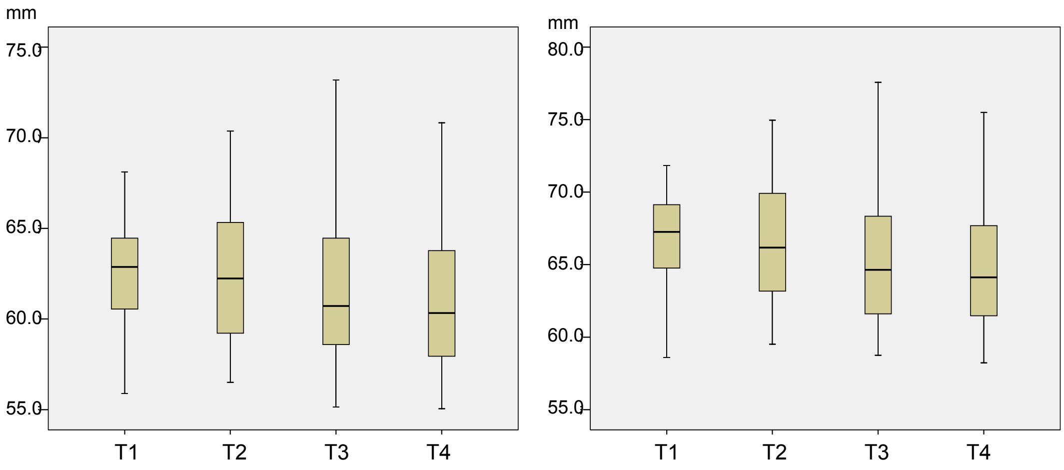


Fig 27 : Box-plots of maxillary arch length and perimeter measured at pre-treatment (T1), after-expansion and during fixed appliance treatment (T2), post treatment (T3) and post retention (T4).

4.5 Comparison of treated and untreated sample groups

4.5.1 Comparison of pre-treatment forms of treated group at pre-treatment (T1) and untreated group at first observation period (T1) (Table 9)

Both maxillary and mandibular arch depths in treated group were broader than those in the untreated group. All of the maxillary arch widths (occlusal and palatal aspects) were smaller in the treated group compared with untreated group but these data are non-significant ($P<.05$). On the other hand, all of the mandibular arch widths (occlusal and lingual aspects) included the maxillary and mandibular arch length and perimeter, were found greater than those of the maxillary values (Table 9).

4.5.2 Evaluation of RME treatment effects (T2-T1 changes) in treated group compared to untreated group (Table 10)

After the expansion of RME in maxillary arch, it was found that all of the maxillary dental arch width increments showed the greater values of changes compared with untreated samples. The difference of the other mandibular values from T1 to T2 showed the greater increments in the control group included maxillary and mandibular arch depths, arch lengths and arch perimeters. The greater changes of overjet and overbite of the control group were found with respect to the treated samples.

4.5.3 Evaluation of RME followed by fixed appliances treatment effects (T3-T1 changes) in treated group compared to untreated group (Table 10)

The treatment changes of the treated samples, who underwent RME followed by fixed appliance orthodontics treatment, produced significantly greater increments in all variables for maxillary and mandibular dental arch widths both occlusal and lingual aspects compared with the control samples. Dental arch depth, length and perimeter of both dental arch showed the smaller increment changes in treated group.

4.5.4 Evaluation posttreatment changes (T4-T3 changes) in treated group compared to untreated group (Table10)

In the treated sample group, there were significant differences (P<.05) in the post treatment changes compared with untreated sample group. It was found that all of the dental arch width changes in treated group showed more differences than untreated group from the end of treatment (T3) to retention period (T4). The maxillary and mandibular arch depths, arch lengths and arch perimeters were found non-significant of the small amount of changes in untreated group compared to treated group.

4.5.5 Evaluation of overall changes (T4-T1 changes) in treated group compared to untreated group (Table 10)

The comparison of the changes in the overall observation period from T1 to T4 between two groups showed the greater changes of dental arch depths and widths in treated group when compared with untreated group. The maxillary and mandibular arch length and perimeter changes were found greater in untreated group but these changes showed no significant differences (P<.05).

Measure (mm)	Treated group (n=32)		Untreated group (n=32)		t *test*
	Mean	*SD*	*Mean*	*SD*	P
Maxillary arch depth	27.82	2.80	26.16	2.28	*
Mandibular arch depth	22.22	1.70	21.89	1.48	NS
Maxillary dental arch					
Maxillary arch width (occlusal)					
Intercanine	30.51	2.17	31.59	2.48	NS
Interfirstpremolar	37.26	2.47	38.13	2.59	NS
Intersecondpremolar	42.48	2.98	42.70	2.36	NS
Intermolar	48.71	3.15	49.10	2.45	NS
Mandibular dental arch					
Mandibular arch width (occlusal)					
Intercanine	26.13	1.63	25.35	2.19	NS
Interfirstpremolar	32.21	2.37	31.97	2.04	NS
Intersecondpremolar	38.20	2.27	37.78	2.30	NS
Intermolar	44.48	2.88	43.07	2.44	*
Maxillary dental arch					
Dental transarch width (lingual)					
Caninetransarch width	24.07	2.24	24.86	2.34	NS
Firstpremolartransarch width	26.08	1.97	26.58	2.12	NS
Secondpremolartransarch width	29.84	2.15	30.03	1.94	NS
Molartransarch width	33.64	2.44	33.90	2.02	NS
Mandibular dental arch					
Dental transarch width (lingual)					
Caninetransarch width	21.20	1.90	20.40	1.86	NS
Firstpremolartransarch width	25.61	1.89	24.51	2.06	*
Secondpremolartransarch width	29.50	2.08	28.70	2.23	NS
Molartransarch width	33.20	2.10	31.92	2.13	*
Maxillary Arch length	70.79	4.78	68.59	4.17	NS
Maxillary Arch perimeter	73.60	4.56	73.05	4.44	NS
Mandibular Arch length	62.37	2.98	60.69	2.76	*
Mandibular Arch perimeter	66.62	3.60	64.73	3.51	*
Overjet	3.61	1.83	3.02	1.73	NS
Overbite	2.60	2.10	3.90	1.50	*

*P>.05; NS, not significant.

Table 9 : Comparison of pre-treatment forms of treated group at pre-treatment (T1) and untreated group at first observation period (T1).

Measure (mm)	Treated group(n=32)								Untreated group(n=32)								t *test*			
	T2-T1		*T3-T1*		*T4-T3*		*T4-T1*		*T2-T1*		*T3-T1*		*T4-T3*		*T4-T1*		***T2-T1***	***T3-T1***	***T4-T3***	***T4-T1***
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	P	P	P	P
Maxillary arch depth	-.82	1.73	-1.3	2.08	-.50	0.81	-1.8	2.12	0.44	1.87	-.11	2.41	-.71	1.36	-.82	1.97	*	*	NS	NS
Mandibular arch depth	-.50	1.31	-.63	1.65	-.44	1.07	-1.1	1.40	0.45	1.06	-.39	1.41	-.51	1.21	-.89	1.83	*	NS	NS	NS
Maxillary dental arch																				
Maxillary arch width (occlusal)																				
Intercanine	3.55	2.14	3.76	2.21	0.20	1.11	3.70	2.10	2.47	2.55	3.22	3.02	-.09	1.26	3.13	2.50	NS	*	*	NS
Interfirstpremolar	4.74	2.36	4.52	2.34	0.26	0.87	4.24	2.12	3.15	2.42	3.97	3.33	-.52	1.71	4.00	2.48	*	*	*	NS
Intersecondpremolar	5.08	1.91	5.36	2.05	0.42	0.96	5.05	1.85	3.83	2.72	4.39	3.27	-.31	1.69	4.67	2.29	*	*	*	NS
Intermolar	4.83	2.18	4.50	2.24	0.52	1.42	4.14	2.11	3.37	2.48	3.27	2.94	-.36	1.68	3.79	2.23	*	*	*	NS
Mandibular dental arch																				
Mandibular arch width (occlusal)																				
Intercanine	0.48	1.79	1.54	1.50	0.10	0.61	0.62	1.62	1.39	2.57	0.10	3.27	-.92	1.19	0.00	2.61	NS	*	*	NS
Interfirstpremolar	1.95	1.98	3.26	2.00	0.12	1.07	2.33	1.93	2.62	2.49	1.47	3.16	-.92	1.51	1.60	2.03	NS	*	*	NS
Intersecondpremolar	1.45	2.11	3.14	2.45	0.16	0.83	2.21	2.23	2.85	2.51	1.27	3.42	-.93	1.51	1.43	2.54	*	*	*	NS
Intermolar	0.78	1.78	3.57	2.01	0.09	0.88	2.63	1.84	2.88	2.50	0.31	3.41	-.94	1.80	0.40	2.36	*	*	*	*
Maxillary dental arch																				
Dental transarch width (lingual)																				
Caninetransarch width	2.70	2.33	1.83	1.78	0.15	0.52	0.68	1.91	2.66	2.60	0.9	3.54	-1.1	1.95	0.41	2.30	NS	*	*	NS
Firstpremolartransarch width	2.76	1.88	2.14	1.88	0.13	0.60	1.70	1.78	1.70	2.07	1.18	2.45	-.43	1.40	1.30	1.74	*	*	*	NS
Secondpremolartransarch width	-8.9	2.37	-9.3	2.16	0.26	0.81	-9.7	2.06	-10	2.21	-10	2.62	-.43	1.46	-9.9	2.02	*	*	*	NS
Molartransarch width	4.83	2.74	3.35	2.09	0.18	1.23	2.95	2.19	2.48	1.87	2.34	2.63	-.40	1.52	2.52	2.13	*	*	*	NS

*P>.05; NS = not significant

Measure (mm)	Treated group(n=32)								Untreated group(n=32)								t *test*			
	T2-T1		*T3-T1*		*T4-T3*		*T4-T1*		*T2-T1*		*T3-T1*		*T4-T3*		*T4-T1*		***T2-T1***	***T3-T1***	***T4-T3***	***T4-T1***
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	P	P	P	P
Mandibular dental arch																				
Dental transarch width (lingual)																				
Caninetransarch width	0.01	1.72	0.39	1.57	0.08	0.48	-.45	1.68	1.25	2.40	-1.0	2.86	-.84	1.82	-1.2	2.23	*	*	*	NS
Firstpremolartransarch width	0.85	1.53	2.72	1.79	0.11	0.77	1.92	1.72	2.07	2.23	0.32	2.54	-.80	0.97	0.44	1.78	*	*	*	*
Secondpremolartransarch width	0.93	1.71	2.62	1.86	0.09	0.76	1.85	1.73	2.27	2.37	0.62	3.03	-.76	1.06	0.70	2.29	*	*	*	*
Molartransarch width	0.92	1.43	2.92	1.46	0.20	0.90	2.35	1.43	2.36	1.94	0.41	2.61	-.58	1.16	0.61	2.03	*	*	*	*
Maxillary Arch length	1.78	2.49	1.46	3.57	-.56	1.16	-.10	3.37	0.91	3.49	1.01	4.18	-1.1	2.26	1.87	3.78	NS	*	NS	*
Maxillary Arch perimeter	2.60	2.64	1.68	3.50	-.67	1.32	1.01	3.39	1.80	3.53	1.59	4.55	-.90	1.67	1.70	3.93	NS	NS	NS	NS
Mandibular Arch length	0.07	1.96	-1.5	2.83	-.62	1.39	-1.6	2.34	0.05	2.68	-1.4	3.79	-1.5	2.19	-.49	3.51	*	*	NS	NS
Mandibular Arch perimeter	-.24	2.09	-1.5	2.93	-.56	1.36	-2.0	2.44	-0.3	5.26	-0.9	3.95	-1.8	2.15	-1.1	3.71	NS	*	NS	NS
Overjet	-.67	2.86	-1.4	2.68	0.14	0.71	-1.3	2.60	-.18	1.18	-.81	1.22	0.02	0.87	-.80	1.50	NS	NS	NS	NS
Overbite	-.47	1.62	-.34	2.05	-.06	0.72	-.41	1.98	-.18	0.92	-.92	1.19	0.13	0.81	-.80	1.30	NS	NS	NS	NS

*P>.05; NS = not significant

Table 10 : Comparison of the changes T2-T1, T3-T1, T4-T3 and T4-T1, between treated and untreated groups.

4.5.6 Comparison of the dental arch forms at post retention stage (treated group and untreated group at T4) (Table 11)

At the long term period until post retention, both maxillary and mandibular arch depths were larger in treated group than the untreated group but the amount was not significant. All of the maxillary transverse dental arch measurements of the treated sample group were slightly smaller than the untreated sample group. But for all of the mandibular transverse dental arch measurements of the treated sample group were slightly greater than the untreated sample group. Most of the arch length and perimeter measurements were found greater in untreated group.

Measure (mm)	Treated group (n=32)		Untreated group (n=32)		t *test*
	Mean	*SD*	*Mean*	*SD*	P
Maxillary arch depth	26.03	2.46	25.35	1.81	NS
Mandibular arch depth	21.15	1.91	21.00	1.62	NS
Maxillary dental arch					
Maxillary arch width (occlusal)					
Intercanine	34.21	2.03	34.73	2.26	NS
Interfirstpremolar	41.50	2.44	42.13	2.27	NS
Intersecondpremolar	47.15	2.48	47.75	2.64	NS
Intermolar	52.50	2.69	53.21	2.78	NS
Mandibular dental arch					
Mandibular arch width (occlusal)					
Intercanine	26.12	2.02	25.35	1.72	NS
Interfirstpremolar	33.81	2.12	33.57	1.71	NS
Intersecondpremolar	39.62	2.45	39.21	2.42	NS
Intermolar	44.88	2.56	43.47	2.90	NS
Maxillary dental arch					
Dental transarch width (lingual)					
Caninetransarch width	24.48	1.56	25.27	2.33	*
Firstpremolartransarch width	27.38	1.50	27.88	1.94	NS
Secondpremolartransarch width	32.55	1.65	33.02	2.34	NS
Molartransarch width	36.16	2.36	36.42	2.48	NS
Mandibular dental arch					
Dental transarch width (lingual)					
Caninetransarch width	20.02	1.35	19.20	1.66	NS
Firstpremolartransarch width	26.04	1.52	24.95	1.53	NS
Secondpremolartransarch width	30.21	1.81	29.40	2.21	NS
Molartransarch width	33.81	2.12	32.53	2.23	NS
Maxillary Arch length	70.69	4.47	70.46	3.43	NS
Maxillary Arch perimeter	74.70	4.68	74.75	3.80	NS
Mandibular Arch length	60.78	3.68	60.21	3.08	NS
Mandibular Arch perimeter	64.58	4.10	63.60	3.58	NS
Overjet	2.31	0.78	2.22	0.94	NS
Overbite	2.19	0.84	3.10	1.23	*

*P>.05; NS, not significant.

Table 11 : Comparison of the dental arch dimensions measurements of treated group at post retention (T4) and untreated group at fourth observation period (T4).

5. DISCUSSION

The aim of this retrospective study was to determine the dental treatment effects among patients who underwent rapid maxillary expansion (Hyrax®-type expander), followed by fixed orthodontic appliance treatment. A total of 32 mixed dentition patients who had complete dental casts at all assessment stages: pre-treatment (T1), after expansion and during orthodontic treatment (T2), post treatment at the end of fixed appliance treatment (T3) and at post retention (T4), were collected. The untreated sample group of 32 children were collected at four observation periods (T1,T2,T3,T4) to serve as control group. The comparison of the differences of the dental arch dimension measurement within the treated group and between the two sample groups was evaluated. The treated samples required a phase of RME to improve the transverse arch dimension before fixed appliance treatment. No active expansion appliances of the mandibular arch were used during the investigation periods.

5.1 Limitation of the study

The purpose of this retrospective study was to investigate the dental treatment effects in long term period after RME followed by fixed appliance therapy. Within the limitation of this study, the dental casts at the assessment stages of the treated group were obtained from annual follow-up records of the routine orthodontic treatment from pre-treatment stage to the post-retention stage. For the control sample group, the dental casts were taken annually to compare with the treated sample group at each assessment stage. The mixed dentition Angle Class II malocclusion of treated and untreated sample groups at pre-treatment was selected to be suitable for the present study.

5.2 The evaluation of the effect of RME followed by fixed orthodontic appliance

5.2.1 Evaluation of the upper and lower dental arch dimensions at each assessment stage in the treated sample group

The maxillary dental arch depth measurements reduced from pre-treatment (T1), after the maxillary expansion therapy and during fixed appliance treatment (T2), to the post-retention periods (T4). These decreases corresponded with the reduction of overjet along the assessment stages which were due to the broadening of the dental arch width followed by expansion therapy and the movement of the upper incisor teeth. The depth reduction improved the excessive overjet of the Angle Class II malocclusion patients. Moreover, the mandibular dental arch depth was also decreased during the assessment stages which compensated for the reduction of maxillary arch depth, but these amounts were smaller than those from maxillary arch depth.

The study of Vargo J. et al. [19], in contrast to this current study, showed the increases in maxillary arch depth during treatment followed by the decreases after treatment to post-treatment stages. The net change of these increases was approximately 20% maintained to post-treatment stage. They explained that this increase was due to the anterior movement of the incisors. Nonetheless, this study investigated the treatment effects of the Haas Type expanders or quad-helix appliances by slow maxillary expansion mechanic, combined with a mandibular banded Crozat/lip bumper.

Geran R.G. et al. [22], similar to this present study, showed the decreases in maxillary and mandibular dental arch depths. They evaluated the effects of the acrylic splint rapid maxillary expander in the early mixed dentition followed by fixed appliances in the permanent dentition. In the treated sample group, they found the consistent losses of dental arch depth in both arches during treatment to the post-treatment period.

As for the measurement of the maxillary and mandibular dental arch widths on the occlusal and lingual aspects, the maxillary intercanine width (occlusal) was found to increase significantly by the amount of 3.56 ± 2.17 mm from pre-treatment (T1) to after expansion and during fixed appliance treatment (T2) which was a response to the expansion of RME appliance at the canine anchored teeth. A decrease in these values from after expansion and during fixed appliance treatment (T2) until post-retention (T4), has been recorded but these decreases were minimal and have no significant statistical differences. The net gain of the maxillary intercanine arch width which was maintained until the post-retention stage was 3.70 ± 2.10 mm.

All of the previous studies [2,14,17,19,24,26,29,38] showed similar results on changes in maxillary intercanine widths after maxillary expansion therapy among mixed dentition and permanent dentition subjects. They found the increases in intercanine width during treatment after expansion and a partial relapse of the width gain at post-retention stage. However, a net gain of 2-4 mm was maintained. Moussa R. et al. [26] stated that the amount of net increases in the intercanine width after the rapid palatal expander presented good stability of the expansion treatment.

From this present study, the intercanine width on the lingual aspect was also measured. It was found that there was an increase in the maxillary caninetransarch width (lingual) from T1 to T2 following the maxillary expansion therapy, followed by a decrease in these values from T2 to T4 with regard to the maxillary intercanine width (occlusal). These changes can be explained by the excess expansion to attain overcorrection during the first period of treatment on anchored canine teeth. After expansion, these teeth were tipped lingually by treatment effect of fixed appliances to bring these teeth into the correct position.

There was a significant increase in the intercanine mandibular width (occlusal) values of 0.48 ± 1.79 mm from T1 to T2 (pre-treatment to after expansion and during fixed appliances), which might be associated with the expansion of the maxilla and the uprighting of mandibular canines. There was a subsequent decrease in these values from T2 to T4 (after expansion and during fixed appliances to post-retention). The total changes of these values from pre-treatment to post-retention (T1 to T4) showed a relapse of this width. The measurement at post-retention period closely approximated those at pretreatment; there were 26.13 ± 1.63 mm at pre-treatment and 26.12 ± 2.02 mm at post-retention, respectively. This can be confirmed by the results of the other dental arch dimension change studies [6,26,34,35,39,40,41], which reported that there was a subsequent decrease after retention of the expanded mandibular intercanine width induced by treatment. The decrease resulted in a final width that was either smaller than the pretreatment value, or that which was closely approximated.

The value of mandibular caninetransarch width (lingual) from this current study was maintained from pre-treatment (T1) to after expansion and during fixed appliances (T2). The decrease in these value was recorded after T2 to post-retention (T4). This result is similar to those of Lima et al. [34] which also measured the lingual aspect of mandibular intercanine width. They reported the increase in intercanine width at lingual aspect from pre-expansion (A1) to short-term follow-up (A2) and the decrease in this value from short-term follow-up (A2) to long-term follow-up (A4).

The measurements of maxillary and mandibular inter-first premolar, inter-second premolar, intermolar widths (occlusal), first premolar, second premolar, molar transarch widths (palatal/lingual) showed similar alterations during the assessment stages. There was a significant increase in the occlusal and palatal/lingual dental arch widths from the pre-treatment to after expansion and during fixed appliance treatment (T1 to T2), which related to the immediate expansion therapy. After the increase at the first observation period, the decrease and increase at the following periods from T2 to T4, were observed. These may be associated with the uprighting of the maxillary and mandibular posterior teeth after expansion and fixed orthodontic treatment.

Many studies [2,7,8,10,14,17,24,29,39,40] examined the dental arch dimension changes following the RME treatment. Some [2,24,29,39,40] showed the net increases in the maxillary intermolar widths when compared with those at post-retention to pre-treatment. Some [6,39,40] reported the increases in both dental arches in intermolar width, but the increase in mandibular intermolar width was smaller than maxilla. The study of Moussa R. et al [26] reported an increase in maxillary and mandibular intermolar widths during treatment, followed by a decrease in maxillary intermolar width and an increase in mandibular intermolar width after retention. In addition, McNamara et al. [8] and SandikÇioğlu M. and Hazar S. [14] ,measured both interpremolar and intermolar widths and the increases in these widths at the end of the observation period were achieved. This current study showed the similar result to all of the studies mentioned above.

Only a few studies examined the dental arch dimensions after RME treatment on the palatal/lingual aspect. One of these was the study of Lima A.C. et al. [34], which investigated the mandibular dental arch dimensions, not only on the occlusal aspect, but the lingual aspect as well. They examined the spontaneous mandibular arch in response to rapid palatal expansion. The dental arch dimensions of mandible on both occlusal and lingual values were examined. The results showed statistically significant increases in mandibular intermolar width in both the occlusal and lingual values when compared with those between pre-expansion (A1) and short-term follow-up (A2). The significant decreases in intermolar width on occlusal aspect and non significant changes on lingual aspect were found from short-term follow-up (A2) to long-term follow-up (A4). The overall changes from A1 to A4 were significant mandibular intermolar width increases on both lingual and occlusal aspects. This result is similar to this present study in which the net significant increases in occlusal and lingual mandibular intermolar widths were also found.

The measurement of maxillary and mandibular arch lengths and perimeters showed the same pattern of the alteration through the assessment stages which is probably because of the compensation of the two dental arches during the orthodontic treatment. From pre-treatment (T1) to after expansion and during fixed appliances (T2), there was an increase in these values followed by a decrease from T2 to post-retention (T4). In this present study, it was found that the net change in the maxillary arch perimeter increase was 1.01 ± 3.39 mm and the loss of mandibular arch perimeter was -2.0 ± 2.44 mm. The net changes in maxillary arch length were -0.10 ± 3.37 mm and -1.6 ± 2.34 mm in mandibular arch length, respectively.

Furthermore, most of the studies [15,16,19,23,26,29,43] on rapid maxillary expansion procedures reported the increase in maxillary arch perimeter after the expansion period, which is similar to the result of arch perimeter changes in this present study. They showed the increase in maxillary arch perimeter during treatment and followed by the decrease after retention. There were many different reports on the net changes in these values from pre-treatment to post-retention. The results ranged from 1.6 mm [26] to a maximum of 6.0 mm [19,23]. Moussa et al. [26] found the net increases of 1.6 ± 5.4 mm in the maxillary arch perimeter from dental cast measurements among patients treated with rapid palatal expanders. However, they reported that these net increases in maxillary arch perimeter related to a large individual variability and were neither statistically nor clinically significant. The statement of

McNamara J.A. Jr. [23] in an overview of American Journal of Orthodontics and Dentofacial Orthopedics in 2006 was that the treated subjects at long-term observation (T3) had 6.0 mm of maxillary arch perimeter gain in comparison with the controls after RME treatment followed by fixed appliances. The study of Lampraski Don G. et al [43] aimed to determine the differences of dental expansion produced between 2-point and 4-point palatal expanders found that both appliances had a significant amount of maxillary perimeter increase between immediately after appliance insertion (T1) and at the end of active expansion (T2).

For the mandibular arch perimeter, different results among these values were obtained from many studies. Some studies [22,26] reported the increase during treatment followed by the decrease during post-treatment, but the net changes showed the decrease, which is similar to this present study. Geran et al. [22] reported only the decrease in these values from during treatment to post-treatment. The net changes of -3.7 mm at post-retention showed the decrease in mandibular arch perimeter compared to pretreatment. The study of Moussa et al. [26] reported the increase after treatment followed by the decrease at after retention. The net decrease was -0.6 ± 4.1 mm, which was not statistically significant. On the other hand, the investigation of Lagravere M.O. and Flores-Mir C. in 2006 [13] who investigated adolescent patients treated with RME and fixed appliances, showed the net changes in the increases in both maxillary and mandibular arch perimeters.

For the result of maxillary and mandibular arch lengths, there was a study of Moussa et al. [26] which reported an increase in maxillary and mandibular arch lengths during treatment and followed by a decrease after retention, but the net changes resulted in no treatment gain. Lima et al. [34] examined the treatment effect on the mandibular arch and found no changes in arch length from pre-expansion (A1) to short-term follow-up (A2). The significant decreases were found from A2 to long-term follow-up (A4), but the overall changes compared between A1 to A4 showed significant decrease which is similar to this current study.

5.2.2 Comparison of the pre-treatment forms of the dental arches at pre-treatment stage (T1) in treated sample group to the first observation period (T1) in untreated sample group

Before treatment, the treated sample group had initially narrower maxillary dental arch width compared to the control group. However, most of the maxillary arch width values showed no significant differences of these two sample groups. On the contrary, the treated sample group had broader mandibular dental arch width than untreated sample group, but these values were not significantly different. This finding was observed from the collected Angle Class II malocclusion treated sample group of 11 unilateral crossbite, 5 bilateral crossbite, 10 lateral edge-to-edge posterior bite and 6 tipped maxillary posterior teeth patients, and Angle Class II malocclusion untreated sample group without crossbite. The treated group showed narrow maxillary dental arch, but the mandibular dental arch dimensions were equivalent to untreated group. Regardless, the slightly small mandibular dental arch dimensions of the untreated were due to the lingually tipped posterior teeth to compensate to the narrow maxillary dental arch to achieve a normal occlusal function. This finding showed more tipped mandibular posterior teeth in Angle Class II malocclusion in untreated group in relation to those in Angle Class II malocclusion in treated group at pre-treatment period.

According to the study of Lux et al. [42] who compared the skeletal base widths and dental arches of Class II subjects to Class I subjects and the good-occlusion groups, they indicated that the maxillary dental arch intermolar width was significantly smaller in Class II subjects group from 7 to 15 years of age when compared to Class I subjects and the good occlusion groups. However, there was no significant difference of the mandibular dental arch width between Class II subjects and control Class I subjects. It can be concluded that Class II patients have normal mandibular dental arch width similar to Class I or good-occlusion group, although they have narrow maxillary dental arch widths.

Furthermore, the maxillary and mandibular dental arch depths, lengths and perimeters of treated group had greater values than those of untreated group. This is associated with the narrow dental arch width values of the treated group. The study of McNamara et al. [8] and Geran et al. [22] compared the measurements of the starting forms of mixed dentition treated group to untreated group. Contrary to this current study, they found that there were significant small values of most of the maxillary and mandibular arch widths, depths, and perimeters of the treated group when compared with the control group. However, there was an exception of the larger mandibular intercanine width of the untreated group at pretreatment from the study of Geran et al [22].

5.2.3 Evaluation of RME effects (T2-T1 changes) on treated group compared to untreated group

The evaluation of the active treatment effects on treated group after RME therapy in this present study showed significantly larger maxillary values of dental arch widths of both occlusal and lingual aspects relative to untreated group. Significant differences in changes between two groups were found at the posterior teeth. This is because of the posterior teeth, i.e. first premolar and molar teeth which were mostly selected for the anchorage of RME appliance, in which forces were directly exerted from the expansion of RME. This present study is in agreement with the other studies [8,22,39],that the maxillary dental arch widths of treated subjects resulted in greater increment changes than untreated subjects.

Moreover, the increases in the different changes in the mandibular dental arch widths of the treated group showed smaller increments both in the occlusal and lingual aspects. These values showed the small inclination changes of tilted mandibular posterior teeth in treated group than those in the untreated group. Therefore, it can be concluded that the mandibular posterior teeth in treated group showed the minimal upright between pre-treatment (T1) and after expansion and during fixed appliances (T2). This should be because of the excessive constricted maxilla at pre-treatment and the treatment effect of fixed orthodontic appliances in the treated patient group. On the other hand, the study of McNamara et al. [8] and Geran et al. [22] reported the different results of small increment changes in occlusal and lingual values of mandibular dental arch width in untreated group between pretreatment and after expansion and fixed appliance therapy when compared to treated group. The control group of these two previous studies was selected from the University of Michigan Elementary and Secondary School Growth Study which had predominantly Angle Class I malocclusions and a few tended towards Angle Class II malocclusion [52]. The control sample group of this current study had only Angle Class II malocclusions.

As for the maxillary and mandibular dental arch depths, a great decrease in the treated group was found with respect to control group. This effect was due to the increase in dental arch widths after the dental arch expansion treatment which benefited orthodontic treatment of Angle Class II malocclusion patients with excessive overjet at pre-treatment stage. By the observation of arch perimeter and arch length, there was an increase in maxillary arch perimeter of 2.60 mm associated with a slight loss of mandibular arch perimeter (-0.24 mm) in treated group. In untreated group, the increase in maxillary and the decrease in mandibular arch perimeters also occurred, but these increments showed a small amount when compared to the treated group during the same time period. There were also greater increases in maxillary and mandibular arch lengths in treated group when compared to untreated group which associated with the increase in arch perimeter. The loss of mandibular arch length (-1.4 mm) in untreated group was found.

The measurements of overjet and overbite of treated group resulted in more changes between after expansion and during fixed appliances (T2) to pre-treatment (T1). This should be the effect of the greater changes in the dental arch widths and depths in the treated group. In addition, the changes in overbite at this period is probably due to the anterior teeth positions, the downward and forward movements of the maxilla [9] and the spontaneous correction of Angle Class II malocclusion [23] after RME treatment.

There were some studies [8,19,22,34,39,44] which showed the comparison of RME treatment effect on treated subjects to untreated controls. Some studies cannot be selected to compare to the present study because of a different control group, i.e. the adult control group of the study of Handelman et al [19]. However, the study of McNamara et al. [8] had mixed dentition control sample group. They found significantly greater increments in all variables for maxillary and mandibular arch widths and the increase in maxillary and mandibular arch perimeters in treated group when compared to untreated group for the evaluation of treatment effect (the different changes between after expansion and fixed appliance therapy (T2) to pretreatment (T1)). In this present study, a similar result of increase in the maxillary arch perimeter was found, but a loss of mandibular arch perimeter occurred after expansion to fixed appliance therapy (T2 to T1 treatment changes). The study of Geran et al. [22] also showed the same result of the greater increments in all maxillary and mandibular arch width variables in treated group. Furthermore, they found significantly greater decreases in maxillary arch depth in the treated samples with respect to the control samples which was similar to the decreases found in the present study.

5.2.4 Evaluation of RME followed by fixed appliance treatment effects (T3-T1 changes) in treated group compared to untreated group

The evaluation of active orthodontic treatment effect among treated group after RME followed by fixed appliance treatment of this current study, resulted in a similar observation as the effect of treatment after RME. There were significant greater changes in maxillary dental arch widths (occlusal) and transarch widths (palatal) with respect to untreated group. After the first period of RME treatment (T2-T1 changes), the difference changes in mandibular dental arch widths (occlusal) and transarch widths (lingual) among treated group showed the significantly greater increases at the end of the fixed appliance treatment when compared to untreated group. Therefore, it can be concluded that the treatment effects of RME followed by fixed appliance treatment produced the increase in both maxillary and mandibular dental arch widths. These increases are the result of the expansion of maxilla which induced the buccal uprighting of mandibular posterior teeth after the correction of excessive constricted maxilla. Although the expansion therapy was followed by fixed appliances, the total net increases in maxillary and mandibular dental arch widths at the end of the orthodontic treatment are maintained.

The study of Moussa et al. [26] reported the treatment effect of RME followed by fixed orthodontic appliances without the comparison to untreated control group. They showed similar treatment effects on the maxillary and mandibular dental arch widths as this current study for the treated group. The change differences between after Haas rapid palatal expander and fixed edgewise appliance treatment (T2) to before treatment (T1), increased in the maxillary intercanine width of 3.6 ± 3.0 mm and intermolar width of 6.7 ± 4.1 mm, respectively. For the mandibular intercanine and intermolar widths, they also reported the increases of those between after treatment and pre-treatment. They were 1.8 ± 1.7 mm of intercanine width and 2.0 ± 3.0 mm of intermolar width.

All of the measurements of maxillary and mandibular dental arch depths, arch lengths and arch perimeters from this present study, showed the similar pattern to the dental arch width pattern. The greater change differences in treated group were found with respect to untreated group. Because there were few studies which examined the RME effect without control untreated group, a comparison of this study can be performed at least indirectly with the results of Moussa et al. [26]. They reported the treatment effect of RME followed by fixed appliances and also found the mean increases in maxillary and mandibular dental arch perimeters and those in arch lengths at post-treatment (T2) similar to this current study.

5.2.5 Evaluation of post-treatment changes (T4-T3 changes) in treated group compared to untreated group

During the post-treatment period, very slight changes occurred in the arch width measurements both in the maxilla and mandibular dental arch widths (occlusal and palatal/lingual aspects) of the treated subjects. In the untreated control group, the reduction of both maxilla and mandibular dental arch widths (occlusal and palatal/lingual aspects) was found. All of the dental arch width measurement changes in untreated group showed the decrease in these values at post-treatment stage with respect to treated group. In addition, the significant differences of both post-treatment maxilla and mandibular (occlusal and palatal/lingual aspects) dental arch width changes in treated samples were reported when compared to untreated samples. All of the other value changes of dental arch depth, length and perimeter between the two groups showed no significant differences.

According to this present study, relapses of the dental arch depth, arch length and arch perimeter of the treated group were found. All of the measurement values were smaller than those at the end of the fixed appliance orthodontic treatment stage. However, the great losses of these measurements were also found in the untreated control group at a similar observation period. This is because of the natural dental compensation of the untreated subjects. The result of the previous studies of McNamara et al. [8] compared the post-treatment changes between two subject groups. They found relapse of the dental arch widths (centroid and lingual aspects) in both treated and untreated subjects during the post-treatment period. Nevertheless, these changes between two groups were not significantly different. This result is not similar to this present study which found the relapse tendency of those values only in untreated group at the similar stage of observation. Furthermore, the maxillay and mandibular dental arch depth and arch perimeter measurements also resulted in the relapse in both subjects from McNamara's study. The great amounts of relapse in the treated group were found from the maxillary intercanine width (centroid and lingual), maxillary and mandibular arch perimeters.

The another study of Geran et al. [22] reported very slight changes in arch width measurements (centroid and lingual) in both the maxilla and mandible of the treated group. They also found the non significant difference of arch width changes among treated and untreated subjects as similar to McNamara et al. [8]. Unlike the previously mentioned study, this present study observed no relapse tendency in arch perimeters after active treatment. The significantly small decreases in maxillary arch perimeter were found in the treated group than those in the untreated, associated with significantly small decreases in maxillary arch depth in the treated group.

5.2.6 Evaluation of overall changes (T4-T1 changes) in treated group compared to untreated group

In the overall observation period, most of the dental arch width changes from pre-treatment to post-retention in treated group showed the increases, except the relapse tendency of mandibular intercanine and canine transarch arch widths. This finding should be considered among the long term changes in the untreated group. In a time period of approximately seven years that covers the late mixed and early permanent dentition, the relapse tendency of these measurements in untreated group has also been observed.

Many studies [6,26,34,41,46,48,49,50,64,66] stated an increase in the maxillary intercanine arch width during treatment and the relapse tendency of the mandibular intercanine width in treated and untreated patients. The study of Ward et al. [46] in 2006, investigated the maxillary and mandibular canine and molar arch width changes in 60 patients treated by fixed orthodontic appliances over 20 years. They recorded statistically significant increases in maxillary intercanine arch width and statistically significant decreases in maxillary intermolar and mandibular intercanine and intermolar widths of the orthodontically treated group between baseline and final follow-up. However, no significant changes were observed for the untreated group. When compared with the untreated group, maxillary intercanine widths increased to a significantly greater extent and mandibular intercanine widths decreased to a significantly greater extent in the treated group. The investigation of the differences over time between treated and untreated groups was statistically significant for upper and lower canine arch widths. The differences of molar arch widths were not statistically significant. In a study by Uhde et al [47], they examined the changes in occlusal parameters among patients from 12 – 35 years of age, who have had previously orthodontic treatments. They reported the finding of mean intercanine width increase in the maxillary and mandibular arches with treatment in all types of malocclusion and the decrease after treatment toward the original values.

The increase in maxillary intermolar width in this present study for the treated group was 4.1 mm, which was about 1 mm larger than that in the control group. These amounts showed the treatment expansion effect of RME therapy which still remained in the long-term observation period. Due to the small maxilla basis at the pretreatment stage in treated group, the increment differences between the two sample groups showed the effective capacity of the RME therapy. Mandibular intermolar width showed an increase of 2.4 mm in the treated group; this amount was about 2 mm larger than the corresponding measurement in the control group. This result showed an indirect expansion effect of RME on mandibular by posterior teeth uprighting.

The treated samples showed great changes in maxillary and mandibular arch depths which were associated with changes in maxillary and mandibular arch lengths and overjet values. The consistent losses of both groups in maxillary and mandibular arch depths were recorded during treatment up to the post-retention periods. The greatest amount of losses in the treated group occurred during the active treatment period compared to those observed in the control group. At the post-retention stage, the loss of dental arch depths was found about 2 times greater in treated group than in untreated group. These losses should be related to the growth development of the patients, the spontaneous correction of Class II patients following the RME therapy [23] and the active reaction of the anterior teeth by the way of fixed appliances. This phenomenon is the favorable treatment effect for the correction of excessive overjet in Angle Class II malocclusion patients.

At post-retention stage, there was an increase in the maxillary arch perimeter changes in treated group and untreated group. No significant differences in the increases in arch perimeter were found between two sample groups. This showed that the effect of expansion therapy by RME followed by fixed appliance therapy which increased the arch perimeter of an excessively small maxilla was found to be similar to the untreated control at long-term period. The loss of the mandibular arch perimeter in both groups was recorded during the observation periods. The findings of this current study support the information of the arch perimeter modifications in growing subjects [36,45]. Most obvious are the conspicuous losses that can be expected in both arches from childhood through young adulthood.

Vargo et al. [19] examined the treatment effects and short-term relapse potential of slow maxillary expansion, with a bonded palatal expander or a quad-helix appliance combined with a mandibular banded Crozat/lip bumper to the end of retention period (12 to 15 months after active treatment). The comparison of the treated samples to untreated controls was determined. The results showed a 6.2 mm treatment gain in arch perimeter of which the

50% approximate of this gain was lost after treatment. For the mandibular measurements, the net gains in mandibular arch perimeter were significantly greater than expected for untreated subjects. Significant post-treatment decreases were observed for mandibular arch perimeter.

This present study is in agreement with the study of Geran et al. [22]. They found the increase in maxillary and mandibular arch widths which were larger in treated group than the corresponding measurements in control group. The greater consistent losses in both maxillary and mandibular dental arch depths in treated than in control groups were also recorded. In contrast to the current study, they found negative changes in both maxillary and mandibular arch perimeters in control and treated groups. Between these two groups, significant long term change differences in arch perimeter were reported. This different result from Geran et al [22] study might be associated with the Class I malocclusion control in their study. However, the increases in these final changes at the end of post-retention period were similar to the present study.

5.2.7 Comparison of the dental arch forms at post retention stage (treated group and untreated group at T4)

At the final long-term observation at post-retention stage (T4), when all the subjects in both treated and untreated samples have ended the active growth period, the initial deficiencies in arch width, depth, and perimeter shown by the treated samples for the controls were almost completely corrected. The maxillary arch perimeter in treated group from the present study was nearly the same in untreated group. Moreover, the mandibular arch perimeter was greater in treated group than in untreated group. From a clinical standpoint, the expansion treatment eliminated the initial deficiencies in maxillary dental arch in all dimensions of arch width, depth, length and perimeter and the indirect expansion effect on the mandibular dental arch dimensions occurred.

A direct comparison of this current study can be performed appropriately with the studies of McNamara et al. [8] and Geran et al. [22]. Nevertheless, these two studies examined the treatment effect of acrylic splint rapid maxillary expander followed by fixed appliances. For the measurement of dental arch width, the maxillary intercanine width increases in both previous studies were similar to the increase reported in the present study (about 4.0 mm). The increase in mandibular intercanine width of this study was about 1 mm, which was smaller than those found in the two studies of 1.5 mm increase. The net increase in maxillary intermolar, interfirstpremolar and intersecondpremolar arch widths in the present study showed the values of about 4 - 5 mm. This result was similar to the increase of 4.4 - 4.9 mm in the other two studies. As for the mandibular arch, about 2.6 mm net increase in intermolar width was found in this current study, which was greater than the 1.0 mm of those found in the study of McNamara et al.[8] and 1.7 mm of those of Geran et al. [22]. Moreover, the definitive changes of 2.0 mm in the mandibularinterfirst premolar and intersecondpremolar arch widths at post retention were found in the present study. These were similar to the result of McNamara et al. [8] (2.0 mm), but smaller than those of Geran et al. [22] (2.7 mm).

As for the measurement of maxillary arch perimeter, in this study, the overall increase was minimal (1.0 mm), but similar to those of Geran et al. [22] (0.9 mm). This amount was small when compared with the increases reported by McNamara et al. [8] (6.0 mm). Mandibular arch perimeter decreased at the overall observation period by -2.0 mm in treated samples which was smaller than those of Geran et al. [22] who found a decrease of -3.7 mm in mandibular arch. However, McNamara et al. [8] found a final overall increase of about 1.5 mm. The different findings from the two previous studies and this current study, should be associated with the stage of dental development of the samples in these three studies. The treated and untreated samples of this present and Geran et al. [22] studies, were in the mixed dentition at the pre-treatment stage, but the subjects in the McNamara et al. [8]'s study were on the average of 12 years of age at the initial time records which were mostly in the permanent dentition.

The observation from this present study when compared with untreated controls in long term suggested that the treatment with hyrax expander in mixed dentition followed by fixed appliance therapy leads to less favorable amounts of relative increases in the perimeter of both arches in comparison with controls. However, a decrease in the dental arches perimeter is the usual occurrence of the growth modification process. The treatment effect of the expansion therapy in transverse dimension of dental arch widths and in sagittal dimension of dental arch depths in both arches, showed favorable outcomes. The expansion followed by RME treatment after the first observation stage remained until long term observation stage. It could be stated that when RME is performed during the early development phases, long term treatment effect and stability are achieved.

5.3 Summarized discussion

5.3.1 Dental arch measurement

The investigation of the dental arch dimension changes after treatment by the RME and orthodontic appliances at each of the assessment stages was reported. Although the different referent points were measured from some of the authors [2,6,14,16,22,26,29,34,35,38,39,40] to compare the change in these dimensions after treatment until long-term period, the results showed towards direction changes in increase or decrease. The dental arch length, depth and perimeter referent points of the measurement are the same in most of the studies, except the transversal measurement of dental arch width. Some [8,22,39] measured at the center fossa between antimere of the posterior teeth. Others [14,26] measured at the cusp tips between right and left sides of the posterior teeth. However, the different changes in increase or decrease in the arch width measurement along the assessment periods should be considered.

5.3.2 Methodology

The patients and control subjects selection are clearly defined and described. These two subject groups are matched for race, sex, and chronological age. The control subjects were chosen from the children without crossbite at the beginning of the investigation. The annual documentation of the control group was taken resembling those of the patients in long-term period. Although some patients had no crossbite at the beginning of treatment, but a sign of maxillary deficiency syndrome was observed in these subjects.

For the measurement of dental arch dimension, it should be realized that changes in the dental arch dimensions during the long-term observation period are influenced by multifactors i.e. the pressure from the muscle on buccal side and that from the tongue, the individual maxillary and mandibular growth development of the subjects, the effect of orthodontic appliances, types of the malocclusion, etc. A few studies [42,52,53] reported the smaller dental arch dimensions of Angle Class II patients when compared to normal occlusion or Angle Class I patients. In adult samples, the study by Staley et al. [52] compared arch widths in normal-occlusion or Class I groups with Class II malocclusions. The maxillary dental arch width was found to be narrower in the Class II division 1 malocclusion than those of Class I group. Bishara et al. [53] compared the dental casts of normal subjects with untreated Class II division 1 subjects from the Iowa Growth Study. The dental arches were analyzed longitudinally at 5, 8, and 13 year of age. The arch width was measured. They found a relative constriction of the maxillary intermolar width in the Class II division 1 group. Alarashi et al [54] investigated the transverse dentoskeletal features of Class II malocclusion around eight years of age.

They found a contraction of the maxilla at both the skeletal and dentoalveolar levels in Class II malocclusion cases.

5.3.3 Results

The results of the current study showed favorable treatment effects after the RME and fixed orthodontic appliance therapy to correct the initial deficiencies of the mixed dentition patients. Although the slight increase in maxillary arch perimeter, and the decrease in mandibular arch perimeter were found, the findings of this study offer an alternative effective treatment of the expansion therapy for the orthodontic patients. Moreover, not only the dental effects in long-term period is of interest, but also the skeletal effect in long-term period. The ages of patients at the beginning of the orthodontic treatment should also be considered. Some more unanswered questions of “Should the expansion therapy be earlier started in the deciduous dentition, which might be shortened the orthodontic treatment period and gives more advantages in the dental and skeletal effects?” or “Could the early expansion therapy in deciduous dentition be stable in the long-term period?” challenged the author.

6. CONCLUSIONS

Therapy with a hyrax-expander RME in the mixed dentition followed by fixed appliances in the permanent dentition can be considered as an effective treatment option to gain space and correct deficiencies of both maxillary and mandibular arches when evaluated in the long term. This RME therapy expands the constricted maxilla to eliminate occlusal interference which induces the normal growth development similar to untreated subjects. Following the maxillary expansion, indirect expansion of the mandibular dental arch occurrs by uprighting of the posterior teeth.

At long-term observation period after treatment, the normal dental arch dimensions of the patients are achieved. Moreover, the RME and fixed appliance treatments are able to produce stable favorable changes in the width and depth of the dental arches. They correct the transverse dental arch width and the sagittal dental arch depth deficiencies by expansion of maxilla, reduction of excessive overjet in Angle Class II malocclusion, and the spontaneous forward correction of the mandibular position.

The present study suggests that hyrax-expander followed by fixed orthodontic appliances should be considered in treating Angle Class II malocclusion among mixed dentition patients with dental arch deficiencies.

7. SUMMARY

This retrospective study was aimed to determine the dental treatment effects on the transverse, sagittal and vertical dimensions of the maxillary and mandibular arches among the mixed dentition patients treated by rapid maxillary expansion (RME) followed by fixed appliance treatment. The subjects of 32 patients, 13 males and 19 females, who underwent rapid maxillary expansion therapy (Hyrax®-type expander), followed by routine orthodontic fixed appliance treatment in the Graduate Orthodontic Clinic at Polyclinic for Orthodontics (Poliklinik für Kieferorthopädie), Ludwig Maximilian University of Munich, were selected, according to the following criteria:

(1) No history of previous orthodontic and orthopedic treatments
(2) No craniofacial anomalies or syndromes
(3) No missing teeth in the upper and lower dental arches
(4) Patients with maxillary constriction
(5) Angle Class II malocclusion
(6) All patients treated by nonextraction therapy during mixed dentition stage

The RME patients were treated with Hyrax-type rapid maxillary expanders (Hyrax expander screw, Forestadent®, Germany), followed by the comprehensive non-extraction orthodontic fixed appliance therapy. No other mandibular active appliances before fixed orthodontic appliances were

performed. The dental casts were collected annually for the routine orthodontic documentation at the assessment stages.

The RME patients group was compared to the untreated subjects of 32 children, 13 males and 19 females, in mixed dentition stage at the beginning of the observation period. These untreated controls were selected based on the same criteria applied to the treated samples with the exception of the maxillary constriction.

The purpose of this study was:

(1) To assess and evaluate the dental treatment effects after rapid maxillary expansion followed by fixed appliance treatment on the maxillary and mandibular dental arch dimensions among mixed dentition patients at pre-treatment (T1), after expansion and during orthodontic treatment (T2), post-treatment (T3), and post-retention (T4) assessment stages.
(2) To examine the changes in the maxillary and mandibular dental arch dimensions in the transverse, sagittal, and vertical dimensions, of the patients and control group in all observation periods.
(3) To compare the difference changes in the maxillary and mandibular dental arch dimensions among mixed dentition patients at assessment stages with the untreated mixed dentition children at four observation periods.

The average age of the control group at the first observation period was 9 years 5 months ± 1 year and the RME group at pre-treatment was 9 years 3 months ± 1 year 6 months.

The measurements of the dental casts for arch dimension investigation at each observation period, were made directly on the upper and lower dental casts by one investigator with an electronic digital caliper, recorded accurate to 0.01 mm.

Differences in dental cast measurements between the two sample groups were compared by means of the student's *t*-test. The paired *t*-test analyses were used to compare within treated group between assessment stages. There was no significant difference between genders within the treated and control group.

The results of this study showed the statistical difference ($p<0.05$) of both maxillary and mandibular dental arch dimensions within the treated group between pre-treatment (T1) to after RME and during RME therapy (T2) and between T2 to post-treatment (T3) periods. During the post-retention period from T3 to post-retention (T4), there was no significant difference ($p<0.05$) of these values. This result showed the effect of the RME followed by fixed orthodontic appliance therapy and the stability in long term period.

The significant difference changes ($p<0.05$) of the maxillary and mandibular dental arch dimensions, after the RME and fixed orthodontic appliance treatments (T2-T1 changes) between patient and control sample groups were found.

It resulted the significant difference changes ($p<0.05$) of both maxillary and mandibular dental arch dimensions between the two sample groups at the end of the RME followed by orthodontic therapy to pre-treatment (T3-T1 changes).

At the retention phase (T3-T4 changes), there were significant difference changes ($p<0.05$) of the maxillary and mandibular dental arch dimensions except the dental arch length and perimeter between two sample groups.

No significant difference changes ($p<0.05$) between the two sample groups at long-term observation period (T4-T1 changes) were observed.

At the end of the observation period (T4), all of the dental arch dimensions of the patients showed the normal dental arch dimensions after treatment in respect to control group.

These findings suggest that RME followed by fixed orthodontic appliance therapy would produce favorable treatment effects among mixed dentition patients with maxillary dental arch constriction.

7. ZUSAMMENFASSUNG

Für eine Studie zur Evaluierung der Behandlungseffekte bei Patienten, die kieferorthopädisch mit der forcierten Gaumennahterweiterungsapparatur (GNE) behandelt wurden, standen die Befundunterlagen von 32 Kindern (13 Mädchen und 19 Jungen) im Wechselgebissalter aus der Poliklinik für Kieferorthopädie im Klinikum der Ludwig-Maximilians-Universität zur Verfügung. Sie wurden nach folgenden Kriterien ausgesucht:

(1) keine vorherige kieferorthopädische Behandlung
(2) keine kraniofazialen Anomalien oder Syndrome
(3) keine fehlenden Zähne (Unterzahl) im Ober- oder Unterkiefer
(4) maxilläre transversale Diskrepanz im Sinne einer Verschmälerung
(5) Klasse II Malokklusion nach der ANGLE-Klassifikation
(6) Patienten im Wechselgebiss mit Indikation zu einer Non-Ex-Therapie

Die Patienten wurden mit einer forcierten Gaumennahterweiterung (Hyrax Expansionsschraube, Forestadent®, Germany) gefolgt von einer Therapie mit festsitzenden kieferorthopädischen Apparaturen behandelt. Im Unterkiefer kamen während der Erweiterungsphase keine aktiven kieferorthopädischen Geräte zum Einsatz.

Zur Beurteilung der Behandlungserfolge wurden jährlich kieferorthopädische Modelle erstellt und ausgewertet.

Die Ergebnisse wurden mit den natürlichen Wachstumsveränderungen bei ebenfalls 32 Kindern (13 Mädchen und 19 Jungen), die keine maxilläre Diskrepanz im Sinne einer Verschmälerung auswiesen, ansonsten aber dieselben Kriterien wie die behandelten Kinder aufwiesen, verglichen.

Zielsetzungen dieser Modellstudie waren:

(1) Erfassung und Auswertung der transversalen, sagittalen und vertikalen Veränderungen der maxillären und mandibulären Zahnbögen sowie der Okklusionsverhältnisse bei den 32 behandelten Patienten der Behandlungsgruppe

- vor Behandlung (T1),
- nach GNE und während der festsitzenden kieferorthopädischen Behandlung (T2),
- nach festsitzender kieferorthopädischen Behandlung (T3),
- und in der Postretentionsphase (T4).

(2) Evaluierung der dreidimensionalen Veränderungen der Zahnbögen und Okklusionsverhältnisse bei den 32 Probanden ohne kieferorthopädische Einflussnahme (Vergleichsgruppe) zu vergleichbaren Untersuchungszeitpunkten T1, T2, T3, T4.

(3) Ableitung der dentalen Behandlungseffekte für Zahnbögen und Okklusion durch Gegenüberstellung der Veränderungen bei behandelten Patienten und unbehandelten Probanden an allen vier repräsentativen Beobachtungszeitpunkten.

Das durchschnittliche Alter der Kinder in der Behandlungsgruppe zum ersten Erfassungszeitpunkt (T1) betrug 9 Jahre 3 Monate ± 1 Jahr 6 Monate, das in der Vergleichsgruppe 9 Jahre 5 Monate ± 1 Jahr.

Die Ober- und Unterkiefermodelle von jedem Untersuchungszeitpunkt wurden von einer Untersucherin mit Hilfe einer auf 0,01 mm Genauigkeit geeichten digitalen Schieblehre vermessen.

Alle Veränderungen zwischen den Untersuchungszeitpunkten innerhalb der Behandlungs- bzw. Kontrollgruppe wurden mit dem *t*-Test bei gepaarten Stichproben statistisch geprüft. Der *t*-Test nach Student (*t*-Test bei unabhängigen Stichproben) kam zur Anwendung, um die Unterschiede zwischen der GNE-Bandlungsgruppe und der unbehandelten Vergleichsgruppe zu ermitteln.

Die Ergebnisse dieser Studie zeigten, dass es keine signifikanten Unterschiede zwischen den Geschlechtern innerhalb der behandelten und unbehandelten Gruppe gab.

Zwischen den Zeitpunkten T1 (Anfangsbefund) und T2 (nach GNE-Behandlung)

- fielen in der behandelten Gruppe signifikante Unterschiede ($p<0,05$) in allen maxilläre, mandibuläre und intermaxillären Dimensionen auf;
- waren die Differenzen der Veränderungen von T1 zu T2 zwischen unbehandelter Gruppe und behandelter Gruppe statistisch signifikant ($p <0,05$).

Zwischen den Zeitpunkten T1 (Anfangsbefund) und T3 (Behandlungsende)

- wurden in der behandelten Gruppe signifikante Unterschiede ($p<0,05$) in allen maxilläre und mandibuläre Dimensionen mit Ausnahme von Overjet und Overbite gefunden;
- zeigten sich statistisch signifikante ($p<0,05$) Differenzen der Veränderungen von T1 zu T3 zwischen unbehandelter Gruppe und behandelter Gruppe.

Zwischen den Zeitpunkten T3 (nach Behandlungsende) und T4 (Postretention)

- fanden sich in der behandelten Gruppe keine signifikanten Unterschiede (p>0,05);
- konnten signifikante (p<0,05) Differenzen der Veränderungen von T3 zu T4 zwischen unbehandelter Gruppe und behandelter Gruppe in allen transversaler und sagittaler Dimensionen ermittelt werden.

Zwischen den Zeitpunkten T1 (Anfangsbefund) und T4 (Postretentionsphase)

- zeigten sich in der behandelten Gruppe signifikante Unterschiede (p<0,05) in allen maxilläre, mandibuläre und intermaxillären Dimensionen;
- konnten keine statistisch signifikanten (p>0,05) Differenzen der Veränderungen von T1 zu T4 zwischen unbehandelter Gruppe und behandelter Gruppe nachgewiesen werden.

Die Ergebnisse dieser Studie beweisen, dass eine GNE gefolgt von einer Therapie mit festsitzender kieferorthopädischen Behandlung bei Patienten mit schmalem Oberkiefer im Behandlungsergebnis zu einer Harmonisierung von Zahnbögen und Okklusion führen, die im Endeffekt als regelrechte Zahnbogengröße eingeordnet werde kann.

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10. APPENDICES

APPENDIX 1 : LIST OF FIGURES

APPENDIX 2 : LIST OF TABLES

Tables Pages

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